I.1

Modeling and Analysis of Human Behavior from Robotics

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INTRODUCTION: Understanding the mechanism for realizing the adaptability of human and animal motions is still an open research issue. For such research, it is crucial to build a sufficiently detailed and precise model of the human locomotory system to quantitatively analyze and estimate signals in the nervous system. Previous effort towards such models has focused on either simplified macroscopic model of the musculoskeletal system [1] or microscopic models of the mechanical [2, 3] and sensory [4, 5] characteristics of the muscle. This paper is an extension of our previous work [6, 7] on modeling the neuromuscular system by a neural network representing the feedforward and feedback loops between spinal nerve signals and muscles.

The model parameters are identified by first measuring several sequences of motions using an optical motion capture system. Combined with our musculoskeletal model [8], we have demonstrated by a dynamics simulation that the model can replicate patellar tendon reflex by applying an artificial trigger signal to the corresponding spinal nerve. We demonstrate the consistency of the model by using patellar tendon reflex as an example. We analyze the parameters of the learned model in detail with this model.

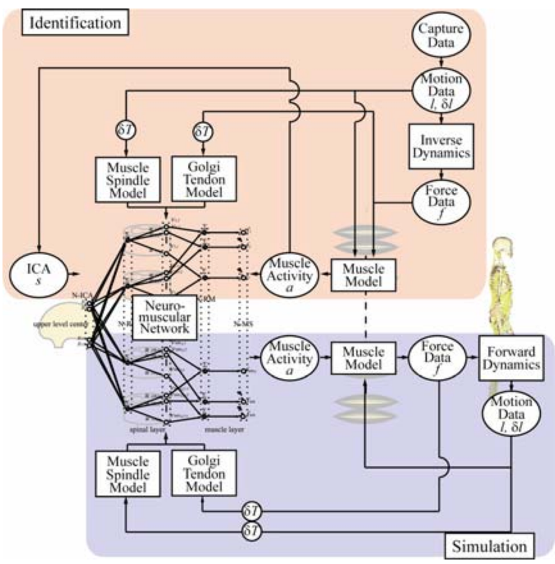

Fig.1. The flows of identification and forward dynamics simulation of the neuromusculoskeletal network model

MODELING THE NEUROMUSCULOSKELETAL SYSTEM: The neural network representing the neuromuscular network [6, 7] was composed of five layers. This model included a human reflex arc model that feeds the muscle tension information back to the inner layer with the time delay for signal transmission. The output of the model was muscle tensions, which were successfully used for simulating motions such as patellar tendon reflex. However, the model has two major problems:

- While our neuromuscular model outputs the muscle tensions, the actual motor commands only determine the muscle activities. Muscle tensions are actually affected by the muscle dynamics and state.
- The feedback signals also include those from muscle spindles that measure the muscle length and its velocity.

The new neuromusculoskeletal model solves these problems by considering the physiological properties of the muscle. Figure 1 illustrates the identification and simulation processes of this model. In the identification, we first compute the muscle tensions from motion capture data using the method described in [8]. The muscle lengths and their velocities are also computed from the joint angles and velocities. The muscle tensions are converted to their activities by a physiological muscle model [2, 3]. In order to derive the command signals from the spinal nerves, we reduce the dimension of the muscle activity data using a statistical technique called independent component analysis (ICA). ICA computes a set of low-dimensional independent components ***s*** that best describes the muscle activity ***a***. The neural network is trained such that it outputs the computed muscle activities when ***s*** are input to the input layer and the muscle lengths, their velocities, and muscle tensions are input to the inner layer as sensory feedback signals. We consider the time delay and muscle spindle model for the feedback loop.

To perform complete simulations of the human body, we have to know the input signals of the spinal nerves, which are actually generated by the central nerve system and very difficult to estimate. However, it is still possible to simulate completely passive motions caused by somatic reflex without voluntary motor commands. These motions could be triggered by passive posture changes due to external forces because the muscle lengths and their velocities are fed back to the spinal nerves. The simulation is performed as follows. We first apply external forces to some parts of the body and compute the resulting motion by a forward dynamics simulation with zero muscle tensions. The muscle lengths would change due to the joint rotations, so there is the change in ***o**ms*. After the time delay of signal transmission *tref*, the muscle length changes are fed back to the inner layer through the somatic reflex loops, which would activate some of the muscles. The muscle activities are converted to the muscle tensions by a physiological muscle model that takes the activity, muscle length, and its velocity as inputs. The muscle tensions and external forces are used to simulate the whole-body motion using the musculoskeletal model. After the second reflex loop, the muscle tensions ***og*** are also fed back with the same time delay *tref*, in addition to the muscle length and its velocity.

Learning and simulation of somatic reflex

A. Learning of neuromusculoskeletal model
We train the neural network model so that its outputs match the muscle activities for a actual human stepping motion (1000 frames, 5 seconds, using an optical motion capture) when the inputs are the independent components computed by ICA of the muscle activities. In this experiment, we set the delay between N-MS and N-MN 30 [msec], which is measured in the human patellar tendon reflex, and is constant for all muscles. We use the lower-body neuromusculoskeletal model in this learning. The number of muscles is 152, and the number of spinal nerve rami is 14.We use the 14 independent components computed from 152 muscle activities as the input of the neural network. The learning loop was repeated 30000 times and resulted in 5:75 [%] average error with 1:32 [%] variance. Figures 2 shows a self-validation result of two muscles, where the horizontal axis represents the time [sec] and the vertical axis represents normalized muscle activities. The blue solid line is the normalized muscle activities we have used for training, and the red dashed line is the output of the neural network.

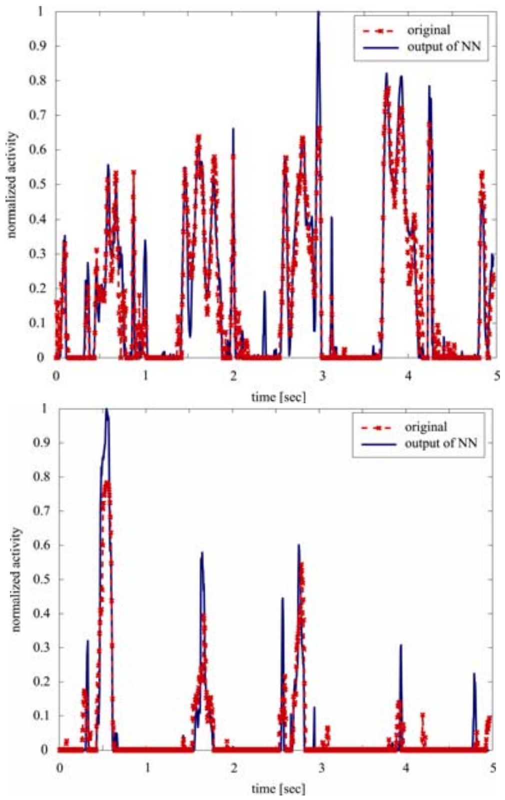

Fig.2 Normalized muscle activity and output of the neural network (top: Rectus femoris, bottom: Extensor hallucis longus)

This graph demonstrates that the neuromusculoskeletal model can sufficiently produce 152 muscle activities from only 14 independent components and state of the musculoskeletal model.

B. Simulation of somatic reflex
We demonstrate the consistency of the proposed model by a dynamics simulation of patellar tendon reflex, a typical somatic reflex invoked by hitting below the knee. The shank pops up due to the tension of the quadriceps caused by its stretch reflex. We use the neuromusculoskeletal model trained in the previous subsection. The hip link of the musculoskeletal model is fixed to the inertial frame, and gravity is applied throughout the simulation. The reflex delay time is assumed to be 30 [msec] and constant for all muscles. The simulation time step is 5 [msec]. We applied an external force to the shank for the first 15 [msec] of the simulation. The external force flexes the knee joint, which in turn stretches the knee extension muscles including quadriceps. The length changes are then transmitted to some of the neurons in the inner layer and activates the muscles connected to the corresponding spinal nerves. The simulation confirms that the resulting muscle activations cause knee extension, the same motion observed in human patellar tendon reflex.
Figure 3 shows the tensions, lengths, and velocities of the three parts of the quadriceps (rectus femoris, vastus lateralis, and vastus intermedius). We apply external force at time 0 [msec], and these muscles are stretched during the latent time of reflex (30 [msec]) due to the external force. These muscles are then activated by the output of muscle spindles which sense the change of muscle length and its velocity. These muscles produce the muscle tensions which cause the extension of knee joint, and shorten themselves. As a result, the output of muscle spindles decrease, and the muscle activities decrease as well. From this graph, the changes of muscle length are about the same in these muscles, but the rectus femoris works mainly in the patellar tendon reflex. Different muscle contributions are learned from the experimental motion data by the neuromusculoskeletal model, and reflect the geometric character of the musculoskeletal model.

CONCLUSIONS: We modelled and identified the neuromusculoskeletal network of the human body, considering the physiological properties of the muscle. The consistency of the model was demonstrated by a dynamics simulation of patellar tendon reflex.
The developed model can be applied to the fields such as biomechanics, neurology, rehabilitation, and sport science. We show one example of the application for the neuromusculoskeletal diseases below. The diseases of neuromuscular system cause the changes of nerve signal transfer between

central nerve system and the peripheral nerve system including the muscles. These changes result in the difference of motion from those of the healthy people. We measure the motions of both the healthy person and the patient using an optical motion capture. Then the parameters of the neuromuscular network can be computed by solving the inverse dynamics and identifying the neural network. The parameters of the networks affected by diseases should be different from those of the healthy person. We can, therefore, find the sites of the disease by analysing and comparing those parameters. In this model, we set the parameters of muscle dynamics as constant. But we can distinguish the nerve and muscle diseases if we treat these parameters as variable. The application discussed above is only one of the usage examples of the neuromusculoskeletal, but there are a lot of ways to apply this model in the fields of diagnoses of neuromuscular diseases, rehabilitation, and sport science.

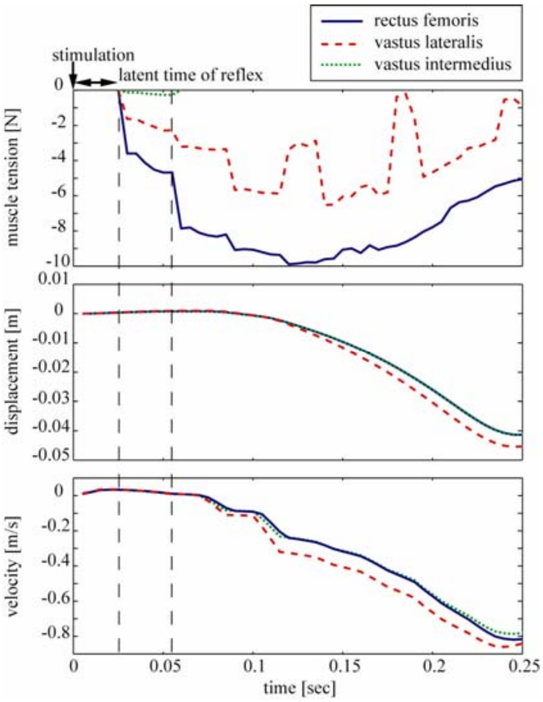

Fig.3 Muscle tension, muscle length change, and its velocity during the forward dynamics simulation

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I.2

Variability and Coordination in Posture and Locomotion Across the Life-Span

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Variability is inherent within and between all biological systems. However, the study of human motor control, including theories of gait and posture, have emphasized in theory and experiment the invariant properties of movement output leaving the variant properties to be compressed into a standard deviation and largely dismissed as reflecting system noise or some kind of error term. Over the last 15 years there has been an increasing recognition that within-subject or intra-individual variability reveals important features of the sensori-motor system output and organization that are beyond what the mean or estimate of the invariant movement property can determine [1-4]. Indeed, an emerging position is that the properties of movement variability may be as or even more useful than the invariant features of movement output in terms of revealing the nature of the processes of movement coordination and control [5-6].

The traditional measure of movement variability in posture and gait, as it has been in all movement tasks, is that of the standard deviation of the distribution of the measures recorded. The standard deviation (SD) is a measure of the amount or dispersion of variability around the mean (M). Sometimes a relative measure of variability is used such as the coefficient of variation (SD/M). These distributional measures of variability do not consider the time evolutionary properties of the series of measures (time-series) and thus important dynamical information (time- and frequency-dependent) of the variability has traditionally been ignored, perhaps because of the implicit assumption that variability reflects the noise of system output [7].

Recent findings show that the general white noise assumption of a normal (Gaussian) distribution and independence between the sequential measures of a range of movement properties often does not hold. Indeed, time- and frequency-dependent structure in the variation of a movement time series is the norm rather than the exception [3, 4]. A collection of methods from time series and nonlinear dynamics is now being used to unravel the time- and frequency-dependent structure of movement variability. This is also the context to mention that averaging movement data across trials and subjects can mask the determination of the structure of the actual within- and between-trial variability so much so that in the worst case scenario the averaged values of the properties of movement variability may not be representative of any trial or subject.

In this talk we will consider the patterns of time- and frequency-dependent structure of movement variability in the coordination and control of posture and locomotion across the life-span. The focus will be on the potential of these measures of variability to discriminate experimental properties and theoretical propositions of gait and posture across population groups in both disease and health states. A central issue is what these distinctions hold for extant theories of gait and posture on issues such as: a) the degrees of freedom (DF) problem, b) the role of noise in movement variability; c) the information used to regulate gait and posture; and d) the time scales and processes of variability.

Dynamical analysis of the time scales of variability reveals the distinctive roles of noise and stability in movement variability. Indeed, the movement variability in posture and gait is driven by time- and frequency-dependent structure leaving the contribution of residual random processes (white noise) to the time-series of movement properties to be very small, and this residual usually includes the various contributions of environmental (e.g., equipment noise). A general emerging perspective is that movement variability in posture and locomotion may be in that class of control processes that are fractal rather than being driven by the distributional principles of central tendency and the law of large numbers [5-6].

The time- and frequency dependent measures of variability have been found to be more sensitive than the distributional measures of SD in revealing differences in movement variability between age groups and individuals with health or disease state problems. Indeed, it appears that changes in the structure of movement variability often occur prior to age and population group changes in the mean of the time series. Thus, movement variability measures may have particular relevance in the clinical practice of movement disorders such as in the screening for disorders and the monitoring of the recovery of function.

A prevalent finding has been that the SD is higher and the dimension (how ever it is measured) of movement variability lower in younger children, older aging adults and movement disorders, but some tasks drive the SD to movement structure relation in the other direction revealing the importance of identifying the constraints on the variability of movement in posture and gait [8]. Task constraints are an important part of the confluence of constraints to action and have a range of influences on the patterns of movement variability. It is also relevant that there are different time scales over which movement variability is determined (e.g., within trial, between trial) and this factor may mediate the inferences about subject, group and task variability.

It is important to note that the measures of movement variability are just that: namely, measures of the variability of a given movement property, even if one used time- and frequency-dependent measures. One is still left with the challenge of deciding what movement property on which to determine the degree and nature of variability. In general, there are too many options available to the experimenter and, therefore, the determination of a set of useful theoretical perspectives and experimental strategies is in order. Here we follow the task dynamics approach and consider variability in 3 movement categories: a) task space; b) individual biomechanical degrees of freedom; and c) the couplings between the individual degrees of freedom. Rarely, has movement variability been considered simultaneously in all 3 categories but it is the mapping of each category to the other that is most informative to understanding motor control through movement variability. Of course, the same experimental and theoretical strategy can be used to study the variability at other levels of analysis, such as brain (EEG), muscle (EMG), and heart (EKG).

An issue to be considered is whether the heretofore largely independent approaches to variability in gait and posture hold the promise of contributing to a unified theory of human movement that encompasses all classes of movement patterns and actions. The potential generalizability of the major findings from variability measures across motor tasks will be addressed. Finally, the significance of the relation between within- and between-subject movement variability in gait and posture will be discussed [9]. Given the inherent non-stationarity of biological systems and its influence on the relation of within- and between-subject variability, the analysis and understanding of the deterministic and stochastic properties of movement in posture and gait becomes even more critical for development of theory and experiment.

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I.3

Posture control modelling with focus on the coordination of postural stabilization and focal movements of the upper limb

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INTRODUCTION: The investigation of the neural control of movement has borrowed techniques of analysis from a number of fields: control engineering, cybernetics, non-linear dynamics, humanoid robotics etc. The problem is that, different from many physiological systems, neural control can never really be dissociated from learning and other cognitive functions, even in apparently trivial problems like upright standing. The control of posture has long been credited to simple reflex feedback mechanisms until a more "ecological" general concept has bee formulated: the equilibrium-point hypothesis [1,2]. It suggested a general purpose "stiffness strategy" for the brain in the generation of control patterns that exploits the "computational affordance" [3] provided by the mechanical properties of muscles. In spite of the elegance of this concept and the fact that it probably explains a large number of motor control issues, its relevance for the standing posture has been contradicted by measurements of ankle stiffness. Thus an active intervention of the central nervous system is required for regulating active ankle torques that stabilize the standing posture. The main challenge for such central controller is that the large delays of the feedback loop, together with the intrinsic instability of the standing body, stress the issues of stability and robustness of the candidate controllers, responsible for the generation of the control patterns. Three classes of controllers will be considered, analysing the pros and cons of each of them: 1) continuous time, linear feedback control; 2) intermittent, non-linear, feedback or feedforward control; 3) predictive control. Moreover, we shall address the control problems that arise when focal movements of the upper limb are associated with postural stabilization, while keeping the position of the feet on the ground, as happens in the activities of daily life: problems of stability (anticipatory postural adjustments) and problems of coordination, related to the high redundancy of the foot-hand kinematic chain (addressed by means of interacting force fields).

POSTURAL STABILISATION MODELS IN QUIET STANDING: Focusing on the anterior-posterior component of sway movements and assuming that the standing body can be assimilated to an inverted pendulum, we can write the following ODE:

$$\ddot{x}_{COM} = -{g}/{h}\left(x_{CoM} - x_{CoP}\right) \qquad (1)$$

where x_{CoM}, x_{CoP} are the positions of the Center of Mass (the controlled variable) and the Center of Pressure (the control variable), respectively, in the A/P direction, respectively. In the absence of control, the system above is characterized by a saddle instability (fig. 1).

Continuous time, linear feedback PD control

A simple control model has been proposed by many researchers [4-6], based on continuous-time feedback with two main components, one proportional to the positional error and the other to the corresponding time derivative:

$$x_{CoP}(t) = K_P\, x_{CoM}(t-\Delta) + K_D\, \dot{x}(t-\Delta) \qquad (2)$$

where Δ is the delay in the feedback loop (a typical estimate is 200 ms) and we assume for simplicity that the reference values for CoP position and velocity are both null. By introducing eq. 2 into the plant model of eq. 1 we obtain a DDE (Delay Differential Equation), whose stability can be analyzed by using the approximation proposed by [7]. It can be demonstrated that stability (with a single point attractor) can be achieved only in a very narrow, triangular-shaped region in the parameter space (K_P - K_D). In this case, the pattern of fig. 1 is substituted by a converging spiral. However, small variations of the control or plant parameters are sufficient to produce a diverging spiral pattern.

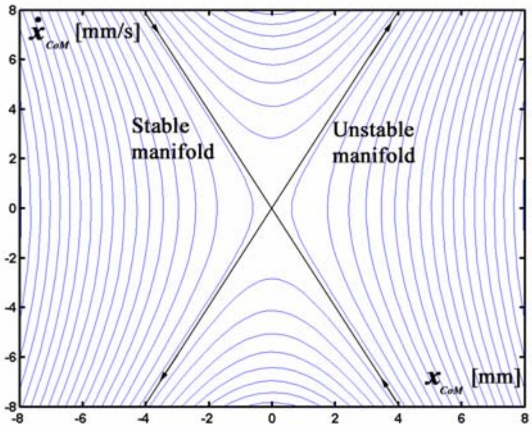

Fig.1 Saddle instability

Intermittent, non-linear, feedback or feedforward control

The idea is to alternate phases in which the controller is inactivated, leaving the system alone, evolving in agreement with the saddle pattern of fig. 1, and phases in which the controller is on. The alternation between the two phases is determined by a switching function, defined in the phase plane. In one version of the control model [8] this function is defined in a stochastic way and the left panel of fig. 2 shows the activation probability, which is zero in the second and fourth quadrants of the phase plane and grows with the distance from equilibrium of the system's state in the other two quadrants. When activation is triggered, an impulsive control signal is generated with amplitude determined by a linear combination of CoM position and velocity. The coefficients of this combination can be assimilated to the K_P and K_D coefficients of the continuous, linear controller.

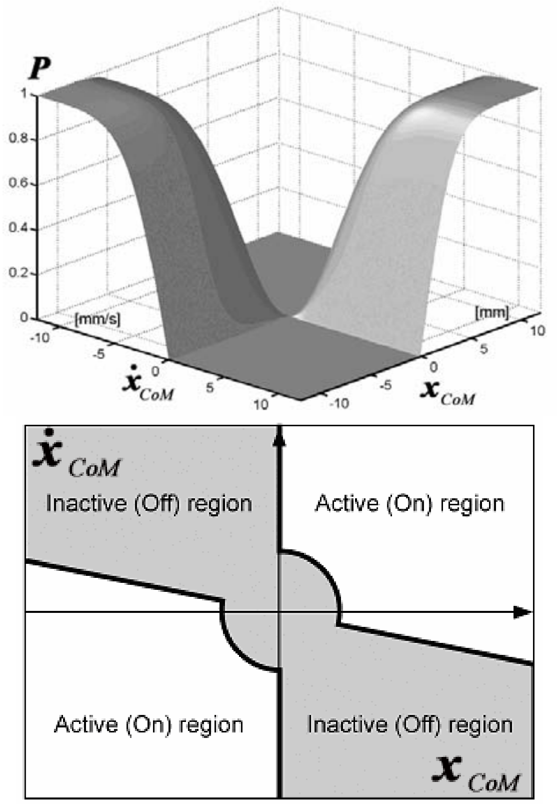

Fig. 2 Switching function of the intermittent controller

Another version of the intermittent controller switches between phases of conventional PD control and phases of inactive control, the alternation between the two phases being determined by the deterministic switching function of fig. 2 (right panel). In both versions of the intermittent controller, active control is switched off when the state of the system is close to the stable manifold of the manifold and is switched off when it approaches the corresponding unstable manifolds. A crucial property of both versions of the intermittent controller is that they have a much larger stability area (in the K_P - K_D parameter space) in comparison with the continuous PD controller, and thus are more robust and less sensitive to changes of the control parameters or plant parameters (e.g. as a consequence of variations of the body posture).

A third type of controller has been investigated in the literature [9]: Predictive Control. The main idea is that in order to attenuate the possible instability induced by the delayed feedback, it is possible to introduce a prediction mechanism that compensates the delay, thus expanding the stability area in the parameter space. However, a prediction mechanism is not very robust, in general, and it is computationally expensive.

WHOLE BODY REACHING (WBR) WHILE STANDING: When reaching beyond arm's length, while standing, people must coordinate the motion of the whole kinematic chain, from the foot to the hand. From this comes the name of whole body reaching, which has been the subject of several studies [10-12]. Here we focus on a computational/generative model, based on the Passive Motion Paradigm [13,14] which is a particular implementation of the above mentioned Equilibrium Point hypothesis [2]. The idea is that in order to coordinate the motion of the redundant number of degrees of freedom of the overall kinematic chain the brain can use an internal model formulated as multiple, interacting force fields: 1) an attractive field, applied to the end-effector of the kinematic chain, directed to the target of the focal movement; 2) a second attractive field, applied to the hip of the body-schema, related to the distance of the CoM from its reference position. The use of virtual force fields allows to take into account the high-degree of redundancy of the body kinematics. The model also includes a non-linear control element that provides the desirable properties of "terminal attractor dynamics" and a set of controllable joint admittance parameters that allow distributing the motion of the kinematic chain to the different joints in a task-oriented way. In general, PMP-based models can be represented as networks [14], articulated in a task-dependent manner. Fig. 3 shows a typical, basic configuration that dynamically links movement and effort vectors in the extrinsic space (of the end-effector) and the intrinsic space (of the joints). Internal and external constraints can be represented by means of force fields mixed in the two spaces, respectively. For example, in the WBR case the stability constraint is naturally expressed in the extrinsic space. J is the Jacobian matrix of the kinematic transformation; K_{ext} is the stiffness of the target-related force field; A_{int} is the virtual admittance of the joints; $\Gamma(t)$ is the time-varying time base generator that provides terminal attractor properties to the system.

Fig. 4 shows an example of WBR movements to different targets. Please note that the "hip strategy", which is apparent when the target is far away from the support base, is an "emergent property" of the network dynamics and is not explicitly programmed. This control model integrates in the same computational framework the coordination of the redundant degrees of freedom and the problem of maintaining the CoM inside the support base during the reaching movement.

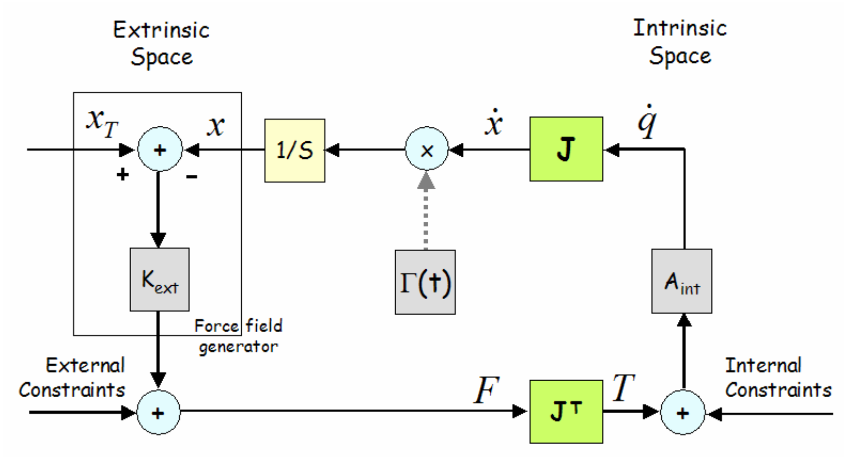

Fig.3 Basic PMP network

However, after reaching, the brain must ensure the stability of the newly acquired posture in an active way, using one of the controllers described above, such as the intermittent controller. Since different terminal postures correspond to different parameters of the equivalent "body inverted pendulum", it is evident that the robustness of the controller is a crucial feature for the stability of the standing body, acting in the general context.

Conclusions: The modelling framework summarized in this manuscript integrates high-level global planning related to focal movements, which is task-dependent, with the lower-level stabilization of the inverted pendulum. The simulation results suggest that the integration is easier and more robust with the intermittent controller.

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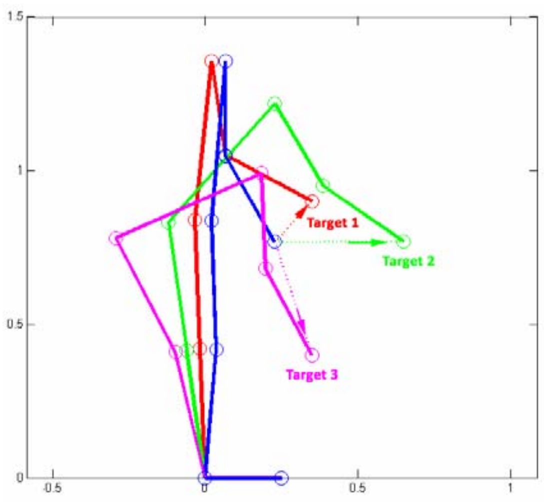

Fig.4 Whole Body Reaching to different targets

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I.4

The real challenge for gait research is challenged gait

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INTRODUCTION: About two thirds of the falls in older people occur while they are walking and most of these falls (85 %) occur in outdoor locations, mostly on the sidewalk and on uneven terrain. Yet even today in gait laboratories most studies involve unperturbed gait while in daily life there are clearly many instances when gait is challenged by different types of perturbations. The goal of the present research was to bring these challenges into the laboratory to gain understanding on the role of reflexes in the reactions to perturbations. A second aim was to learn why some subjects (elderly, patients) fail more easily than young subjects to meet these challenges to gait. After identification of these failed reactions the question will be asked whether these responses can be improved or supplemented with behavior that protects one from fractures.

METHODS: Perturbations involving foot contact

A first series of studies induced stumbles over obstacles which were positioned over a treadmill while subjects were not able to see them approaching [1]. Later a trapdoor box was used that could collapse when subjects stepped on it while they saw the box approaching. The collapse produced an ankle inverting perturbation [2]. These types of perturbations involve contact of the foot with a perturbing surface (obstacles, collapsing surface) and it is therefore tempting to relate the evoked responses to cutaneous reflexes. However, the current hypothesis is that such perturbations are primarily proprioceptive in nature. Furthermore, it has been proposed that widespread reflexes in the leg under these conditions might be due to spread of a mechanical “shock-wave” from the foot upwards, causing stretch reflexes in many muscles. It is thought that these perturbations induce a series of responses in various leg muscles.

RESULTS:

Short-latency reflexes

First there is usually a small short-latency response (40-45 ms; SLR). To induce stumbling on a treadmill one can use an obstacle that is positioned on the belt while subjects are unable to hear or see the obstacle moving towards them on the moving belt [3]. The foot contact with the obstacle causes a proprioceptive perturbation since the ongoing flexion movement during swing is briefly interrupted. Using this technique it was found that the fastest responses in the stumbling leg had latencies between 34 and 42 ms and they appeared in all muscles investigated [4]. This widespread distribution was somewhat surprising since the perturbation is primarily caused by contact of the foot with the obstacle, yet responses are present even in upper-leg muscles. The latencies are so short that a cutaneous reflex can be excluded. Cutaneous responses after nerve stimulation have a longer latency than the fastest responses seen during stumbling. The shortest latency for cutaneous reflexes is around 50 to 55 ms [5]. Hence, it appears that stumbling represents primarily a proprioceptive perturbation and that the first line of defence is the so-called “short-latency reflex” (SLR), a spinal stretch reflex. The amplitude of these early activations was usually quite small, yet these induced contractions may have some importance in providing a brief period of increased muscle stiffness, exactly at a time when otherwise these muscles would have yielded because the short-range muscle stiffness had vanished after the initial stretch [6].

The SLR responses are not limited to stumble perturbations. For example in another series of experiments the effects of induced ankle inversions during gait were studied [7,8]. Subjects walked on a treadmill and were asked to step on a box, the top of which could collapse on one side, thereby causing an ankle inversion. It was found that such perturbations induced SLR responses, not only in the muscles being stretched by the inversion (peroneus longus and brevis) but also in other muscles such as the ankle extensors [7,8]. Hence again the SLR appeared to be a rather non-specific reaction, in the sense that it appears in a large variety of muscles. Muscles spindles are known to be extremely sensitive and this may explain that small mechanical perturbations, even remote ones, can trigger these widespread reactions [9,10].

LLR: Long-latency reflexes

The main response to mechanical perturbations appears at a latency of around 85 to 90 ms and this response is usually much larger than the SLR [11,12]. These responses are referred to as LLR (long-loop reflexes), thereby emphasizing that they probably are due to activity in long loops (presumably supraspinal). This is not entirely established though since there is also evidence that some of these responses originate from the activation of slower conducting group II afferents [13]. In that case the delay is not necessarily due to the long loop but rather to a slow spinal loop. Nevertheless there is increasing evidence for a transcortical loop [14]. The question remains however whether the cortex is the only contributor or whether other structures could also be involved. Indeed a pathway over the brainstem has not been excluded. Earlier studies have supported this latter concept (spino-bulbo-spinal pathway [15]; triggered reactions [16]) and these ideas have again received much attention lately [17].

One thing is quite clear, namely that the LLR differs considerably from the earlier (SLR) response in several aspects. For example, the LLR exhibit more habituation, indicating that they are related to the novelty (unexpectedness) of the stimulation [8]. Furthermore, the LLR are much more specific than the SLR. The muscles that are most heavily recruited in these responses are those that bring about a meaningful global response to the perturbation. In case of a stumble there is a strong activation of the hamstrings, which is meaningful since it can assist the stumbling leg in overcoming the obstacle (knee flexion, [3]) while contralaterally the responses can decelerate the forward momentum of the trunk (hip extensor moment of the hamstrings, [18]). In the case of the ankle inversion, the responses surviving habituation are those occurring in the peroneal muscles, which clearly undergo most of the stretching [7,8].

Often the specificity of the LLR appears more clearly when stimuli are repeated and some habituation has occurred [7,8]. This is because the first trial usually induces large startle-like responses which are present in many muscles. Nevertheless it is conceivable that the late responses are also related to startle, but then in an attenuated form.

How important are these LLR for regaining stability?

For some perturbations the LLR responses appear in muscles in the whole leg but also in paraspinal muscles, indicating that they are part of an automated correcting response Conversely, when these responses are lacking or are too small they may compromise stability. In stumbles of elderly the amplitude of the ipsilateral LLR responses in the hamstrings is much smaller than in young adults and it has been pointed out that this could increase the risk of falling in the elderly since the activation of the hamstrings is essential for proper knee flexion to overcome the obstacle. A similar decrease in response amplitude was also observed in the contralateral leg in elderly [18,19]. Furthermore, it was shown that the ability to recover from a stumble was related to the level of activation of the hamstrings [20]. This prompted some authors to recommend strength training of these muscles in this group of elderly fallers [21].

Avoiding contact with obstacles

Stumbling not always occurs because one fails to observe an obstacle. In many cases the obstacle is seen but the obstacle avoidance (OA) reaction is inadequate and stumbling occurs as a result [22,23]. In these OA reactions there is again a fast early activation of hamstring muscles, even when no stumbling occurs. These reactions have a latency close to LLR responses, well-below the voluntary reaction times (< 150 ms) and they are precipitated by combined startle stimulation [24]. This supports the idea that these responses may be triggered reactions, stored at a subcortical location. The OA reactions are later and smaller in elderly and in amputees. They are also affected by the use of small doses of alcohol (see poster Hegeman et al., this meeting). It is questionable whether these involuntary reactions, with latencies below 150 ms, can be modified (for example by training) in elderly or in patients. Hence the first two lines of defence (SLR and LLR type of responses) offer little hope for protection against falls in these groups. However, it is also evident that subjects can still rely on a third line of defence, consisting of learned reactions having latencies above 150 ms. In falls, which typically occur over a period of 600-800 ms, there is sufficient time to use these reactions to fall in a “safe” way. It is proposed to use fall techniques borrowed from martial arts to reduce fracture risks.

Learning how to fall properly

It was shown that martial arts fall technique result is reduced impact peaks [25]. When compared with controls, subjects that are trained in these techniques show differences in EMG activations from 180-190 ms after the onset of a self-induced fall [26]. Furthermore these martial art fall methods can be learned quite quickly [27] and can be mastered by elderly [28]. It was demonstrated that exercise programs with martial arts training can prevent falls and fall-related injuries in this population [28]. Lately the technique has been adapted to elderly with osteoporosis [29].

CONCLUSIONS: It is concluded that various perturbations during gait induce reactions which are fast and earlier than one would expect from voluntary activations. These reactions are smaller and later in various groups that are at risk of falling (elderly, patients). It is proposed to compensate for these reduced reflexes by focusing on appropriate voluntary strategies to fall safely and thereby to reduce the risk of fractures.

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D.1

Does the equilibrium-point hypothesis help understand postural synergies?

Discussants:

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RATIONALE: The equilibrium-point (EP) hypothesis has been a controversial theory of motor control for nearly 50 years. One of us (ML) plans to show new data suggesting that EP-control of important mechanical variables maps, at a higher hierarchical level, on multi-muscle-mode synergies that, in turn, map on muscle activations. This view will be contrasted by the other proposer (YI) who will suggest that muscle synergies may be viewed as an epiphenomenon of variable maps since they (synergies) are highly task-dependent. According to this view, choice of an EP and its control may represent two relatively independent tasks or levels of control.

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D.2

Preferring preferred speed?

Discussants:

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RATIONALE: When studying gait in people with different preferred speeds, should one use preferred speed (to have gait that is as natural as possible)? Or should one use a common gait speed and force some of the subjects to walk at a non-preferred speed (and thereby reduce variability in the data; but thereby also avoiding the issue of speed-dependent changes over and above group-related changes)? Or a compromise?

Humans can easily sustain non-preferred gait modes but, in the case of walking, “only at a significant attentional/cognitive cost” [1]. Furthermore it is claimed that locomoting at non-preferred speeds (running and walking at 5 and 9 km/h, respectively) shows clear differences relative to preferred speeds with respect to modeling the spatiotemporal organization of motoneuron (MN) activity during different human gaits [2].

On the other hand it is attractive to force people to all walk at the same speed (even if this means non-preferred speed for some) because one can avoid to have to account for speed dependent differences in gait characteristics such as EMG activation patterns [3-5]. Variability is one of the major challenges in this type of research (Visser Clin Neurophysiol 2008), and by standardizing walking speed at least one source of variability is eliminated. Some patients walk at very low speeds and one can be misled in assuming that the EMG activation patterns are abnormal while in reality they are due to the low speed and not to the pathology.

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O.1

Which ankle muscle is the best proprioceptor during human upright standing?

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INTRODUCTION: Human standing is successfully maintained using visual, vestibular and somatosensory information. But it has been demonstrated that normal subjects can stand in a stable manner when receptors in the ankle muscles are the only source of information about postural sway [1]. The actively modulated changes in muscle length and tension in the calf muscles related to standing balance are unlikely to signal postural sways because of their observed paradoxical muscle movement [2-3]. These facts pose a question: Which ankle muscle provide the best proprioceptive information?

METHODS: Nine healthy participants (35±11 years old) stood normally for trials of 30-40 s. Force platform (AMTI) and whole body kinematic data (VICON) were recorded. Changes in muscle length from tibialis anterior, soleus and gastrocnemius were measured using ultrasound. One probe was fixed along the left calf and the other along the left tibialis anterior muscle. Surface EMG (Delsys) data were recorded from gastrocnemius and tibialis anterior. The quantities of interest were calculated for successive 3s intervals and then classified into three categories: "whole trial", "negatively" and "positively correlated", according to the sign of the correlation between muscle length and Centre of Gravity (CoG). The quantities were: standard deviation and mean EMG, correlation between muscle length and CoG of left gastrocnemius, soleus, tibialis anterior (deep and superficial compartments), and percentage duration.

RESULTS: For all subjects, tibialis anterior was mainly un-modulated (duration 84%±9%); and when un-modulated its changes in muscle length had the highest correlation with bodily sway (-0.66±0.07). Gastrocnemius and soleus were usually (duration 71%±23%, 81%±16% resp.) actively modulated to maintain balance but, for short periods of time, they could be un-modulated and then presented a moderate correlation (0.38±0.16, 0.28±0.09 resp.) with body position. For gastrocnemius the mean correlation is comprised of periods when it is negatively correlated (-0.57±0.13), but also when it is unexpectedly positively correlated (0.38±0.16) for 29%±24% of the total duration.

CONCLUSIONS: Considering the duration and extent to which muscle length is un-modulated and correlated with bodily sway, tibialis anterior may be a better source of proprioceptive information than the actively modulated calf muscles. Soleus and gastrocnemius appear to be more suited to an active role to maintain balance, but they still have periods of un-modulated activity in which they can be source of proprioceptive information. The wider implications are: (i) all passive or un-modulated muscles crossing the ankle joint provide better proprioception of standing sway than the active agonist, (ii) reciprocal inhibition may be favoured over autogenic muscle stretch pathways for modulating the active agonist.

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O.2

Plantar sensory degradation on motion perception and postural control

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INTRODUCTION: To examine the balance deficits associated with peripheral neuropathy, some of previous researchers have examined the variations of postural responses such as the center of pressure (COP) and/or center of mass (COM) with different somatosensory manipulations [1]. However, considering that the nervous system generates compensatory motor control based on perceived body motion from multi-sensory information (vision, vestibular cues, and somatosensation), an investigation of perceived motion would be a more direct assessment of sensory deficit, rather than an examination of postural performance. To examine whether subjective motion perception could provide more sensitive assessment of the effect of reduced sensory cues on postural control than the measurement of body sway, we examined the contribution of plantar cutaneous sensation on motion perception and postural control. We examined the change of postural control response using both uni- and multi- variate assessment.

METHODS: Eleven healthy male volunteers aged 20-28 (mean 24.3, SD 2.5) participated in this study. The subjects reported no history of balance disorder, and signed the informed consent form approved by IRB prior to the test. The subjects were translated in the ML direction with various magnitudes of peak acceleration with their eyes closed in the dark, while being subjected to two different cutaneous conditions: the control condition (bare foot) and the reduced cutaneous condition (foot on a spongy surface). The translation stimulus is a single sinusoidal acceleration at 0.25Hz with peak amplitude ranged from 0 to 8mG. For each condition, subject completed six sets of randomly sequenced 33 translation stimuli. After each translational stimulus, subject reported their perceived direction of motion by pressing a hand-held button. To examine the correlation between the motion perception and postural balance control, we measured the COP trajectories and joint kinematics during the 60 sec of quiet stance on the two somatosensory conditions with eyes closed. Threshold data were analyzed using the psychometric function that best matched the perception data.

RESULTS: The spongy surface successfully simulated reduced cutaneous pressure sensitivity. While barefoot, the average pressure threshold level was 4.07 a.u. (±0.18 S.D) and this significantly ($p < 0.0001$) increased to 6.40 a.u. (±0.26 S.D) with the spongy surface. When plantar pressure sensitivity was reduced by the spongy interference, a significant increase in the detection threshold ($p < 0.05$) was observed. There was a significant increase in the deviation of COP in the AP direction ($p < 0.005$) but not the ML direction ($p = 0.08$). While the univariate measure of postural sway demonstrated a significant increase only in the AP direction, the multivariate covariance of quiet stance joint kinematics showed significant differences in both the AP and ML directions for the two different cutaneous conditions.

CONCLUSIONS: A significant increase in perception threshold with reduced cutaneous cues implies that the nervous system significantly relies on plantar cutaneous sensation to perceive the direction of motion, despite the presence of other intact sensory cues such as joint proprioception, vestibular cues. Multivariate covariance analysis describes how joint coordination changes with reduced plantar sensitivity. The observed discrepancy in the significance of the contribution of plantar cutaneous cues to the detection threshold and the COP variation implies that the 'perception' could provide more direct and sensitive assessment of the sensory degradation than the 'action'.

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O.3

Investigating sensory interaction of cutaneous and vestibular systems during stance.

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INTRODUCTION: Standing balance requires sensory information from visual, vestibular and somatosensory systems [1]. Independently, the perturbation of each system has been shown to induce a postural response in healthy individuals [2]. Combined sensory input may be necessary to generate effective reflex activity for balance control in individuals with impaired sensory systems. In the current study, galvanic vestibular stimulation (GVS) was used to perturb the vestibular system; whole-nerve stimulation was used to activate foot sole cutaneous afferents. Both techniques at supra-threshold levels induce short and medium latency reflexes [3,4]. It is hypothesized that sub-threshold activation of the two sensory systems will result in summation at the spinal level and demonstrate a functional response to restore postural equilibrium.

METHODS: Healthy, adult subjects participated in the study. Muscle activity was recorded bilaterally from soleus, medial gastrocnemius, and tibialis anterior. Monopolar, binaural GVS was configured using anode electrodes behind each mastoid process and cathode electrodes on each forearm. GVS threshold was determined through sway activity. Cutaneous reflex threshold was determined from EMG. For testing, GVS and cutaneous stimulation intensity were set at 90% of threshold. Four experimental conditions were tested (anode only, skin only, anode and skin and control; no stimulation). To enable spike triggered averaging each condition was repeated 100 times. EMG and force plate data were collected during stance (eyes closed, feet 1 cm apart). Raw EMG was full wave rectified and smoothed.

RESULTS: Sub-threshold stimulation of each system independently did not significantly modify EMG activity. During co-stimulation of vestibular and cutaneous systems, however, modulation of EMG activity was observed in the soleus muscle (ipsilateral to cutaneous stimulation). A significant (>2 S.D.) ML (onset 117 msec) response resulted in a 16.3% increase in EMG amplitude compared to mean soleus activity. Force plate data indicated a significant sway followed the EMG activity in co-stimulation trials.

CONCLUSIONS: Our data demonstrate the presence of spinal summation from vestibular and cutaneous systems. The importance of this finding is that it suggests the ability to integrate subthreshold sensory information from multiple systems when balance is threatened. However, individuals with sensory deficits are limited in the sensory information they are able to use effectively. Here we have shown that the summation of two sub-threshold sensory sources can elicit a postural response. Therefore, heightening the sensitivity of a system through augmentation of healthy, intact sensory sources can benefit patients with sensory deficiencies.

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O.4

Evidence for the contribution of sensory integration mechanisms to spinal stabilization

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Introduction: Stabilization of the upper body (UB) segment relative to the pelvis is synonymous with the general problem of spinal stability. Most previous studies of spinal stability have focused on the contributions of intrinsic stiffness and stretch reflexes while generally ignoring the role of sensory integration mechanisms. However, previous work in whole-body postural control has shown a major influence of sensory integration mechanisms that act with 150-200 ms time delay [1]. To determine if sensory integration mechanisms contribute to spinal stability, we analyzed UB frontal plane sway responses to visual tilt and pelvis tilt stimuli.

Methods: Frontal plane pelvis tilts were generated using continuous pseudorandom rotations at various amplitudes of the surface that subjects stood on while preventing lateral sway of the lower body (Fig. 1A). Pelvis tilt tests were performed both eyes closed (EC) and eyes open (EO) while viewing a stationary visual scene. Visual tilts were generated using continuous pseudorandom rotations at various amplitudes of the visual scene (Fig. 2A). UB sway from pelvis tilt tests were analyzed by calculating frequency-response functions (FRFs, Fig. 1B) over a range of 0.023 to 10.3 Hz and impulse-response functions (IRFs, Fig. 1C). UB sway responses to visual tilts were analyzed by calculating FRFs over a frequency range of 0.43 to 1.5 Hz (Fig. 2B).

Results: FRF phase (not shown) and gain curves showed consistent amplitude-dependent changes (Fig. 1B). Differences between FRFs obtained at different pelvis tilt amplitudes were limited to frequencies below 3 Hz with FRF gains decreasing with increasing stimulus amplitude. IRFs were nearly identical across all pelvis tilt tests for the first 0.2 s, but showed changes at longer time lags that depended on the pelvis tilt amplitude (Fig. 1C). The availability of visual orientation cues (EO compared to EC) had only a small effect on the UB sway evoked by pelvis tilt stimuli. This small effect of vision was consistent with the small UB sway evoked by visual tilt stimuli as indicated by overall low FRF gains that decreased with increasing visual tilt amplitude (Fig. B).

Conclusions: The UB FRF gain reductions and the time-delayed changes in IRFs with increasing pelvis tilt amplitude are consistent with a sensory integration mechanism contributing to a sensory re-weighting phenomenon in spinal stabilization whereby subjects shifted toward reliance on sensory cues (vestibular with EC and vestibular/vision with EO) that orient the UB toward an upright position and away from reliance on proprioceptive cues that orient the UB to the tilted pelvis. FRF gain reductions with increasing visual tilt stimuli are also consistent with a sensory re-weighting phenomenon, although vision plays only a small role in spinal stabilization during frontal plane sway.

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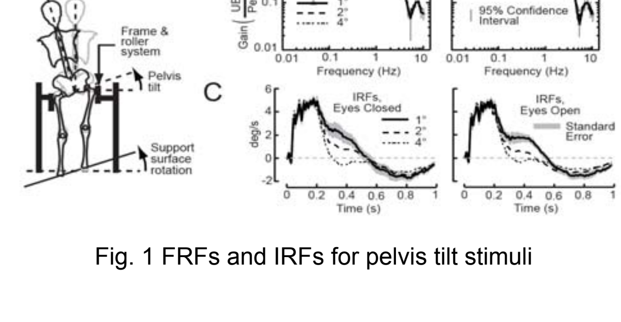

Fig. 1 FRFs and IRFs for pelvis tilt stimuli

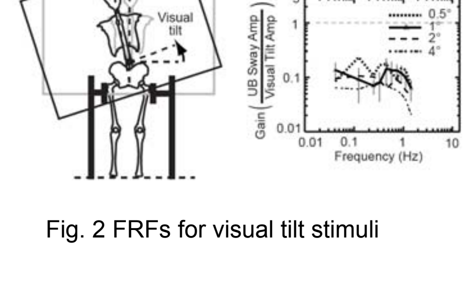

Fig. 2 FRFs for visual tilt stimuli

O.5

Habituation of postural response to repeated Galvanic vestibular stimulation

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INTRODUCTION: We have developed a system for replicating postural instability observed in astronauts after return from space flight, and patients with bilateral vestibular loss, using pseudorandom bilateral Galvanic vestibular stimulation (GVS) [1,2]. In the current study we are assessing whether postural performance habituates to repeated exposure to GVS.

METHODS: The GVS waveform consists of a sum of non-harmonically related sinusoids (0.16, 0.33, 0.43, and 0.61 Hz) with maximum amplitude of ±5mA. Postural performance was assessed with an Equitest computerized dynamic posturography (CDP) system (Neurocom, Portland, OR). Postural performance was evaluated in 13 subjects four times over a 48-h period. Subjects were exposed to 6-min of GVS during each CDP test (total 24-min). In addition, 5 subjects were exposed to 1-h of continuous GVS exposure during ambulation between the 1st and 2nd CDP trials.

RESULTS: Subjects (8) exposed to a total of 24-min of the 5mA-peak pseudorandom GVS analogue during CDP over 4 sessions showed little evidence of habituation (Fig. 1; white trace), with composite CDP score remaining in the clinically abnormal range. In contrast, the balance scores of 5 subjects during GVS returned to the no-GVS baseline ($p=0.03$) after continuous 1-h exposure to GVS between the 1st and 2nd CDP trials (Fig. 1; black trace).

CONCLUSIONS: The results suggest that substantial postural habituation to GVS can occur with sufficient cumulative exposure (> 1 h). Alternatively, these results could indicate that intermittent exposure to GVS does not engender habituation (or it occurs over a much longer time course), and that a period of continuous long-term (~1 hr) exposure may be required.

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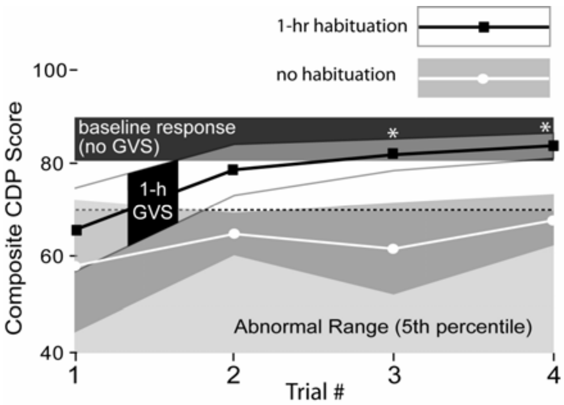

Fig.1 Composite CDP score during pseudorandom GVS over 4 trials. Subjects (8) (white trace – mean and SD) showed little improvement, with postural performance in the abnormal range. In contrast, subjects (5) exposed to 1-h of GVS between the 1st and 2nd trials (black trace) exhibited habituation, with a return of the balance score to no-GVS baseline.

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O.6

Auditory startle reveals possible brainstem involvement in triggering postural responses

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INTRODUCTION: Recent evidence supports a supraspinal contribution to postural responses, however, the mechanisms and neuroanatomical structures involved in triggering their onsets remain unknown. The acoustic startle paradigm is a method used to investigate the potential involvement of brainstem structures, such as the reticular formation, in motor response initiation. For instance, brainstem involvement could be inferred in postural response initiation if a startle-inducing stimulus coupled with an imperative cue initiates a prepared postural response more rapidly than that triggered by an imperative cue in the absence of startle [1]. The current study sought to investigate a) whether postural responses conditioned to an auditory tone could be initiated in the absence of a postural perturbation and b) whether conditioned postural responses could be initiated earlier following a startling acoustic stimulus.

Methods: Participants (*n*=9) first stood quietly on a platform for 1-minute, during which time a generalized startle reaction was triggered by a single, unexpected auditory startle tone (120dB). Two blocks of 20 conditioning trials followed, whereby each conditioning trial involved a non-startling auditory cue that began 200ms before the onset of, and co-terminated with, a toes-up support-surface tilt (12^{o}, 120^{o}/s). Both conditioning blocks were followed by a trial involving a single auditory cue that occurred in the absence of a balance perturbation. Following block 1, the cue was presented alone (Cue-Only) to elicit conditioned postural responses. Following block 2, the cue was followed by a post-conditioning auditory startle that occurred at the expected onset of the support-surface tilt. Electromyographic recordings quantified lower-limb and neck muscular response latencies relative to the onsets of the platform and, when present, the startle stimulus.

Results: Following conditioning, the Cue-Only trials triggered the onsets of tibialis anterior (TA) and rectus femoris (RF) muscles at latencies known to be associated with postural responses (TA:95ms, RF:139ms). Compared to those in Cue-Only trials, response onsets in post-conditioning startle trials were 35ms and 65ms earlier in TA and RF, respectively. Although earlier, the patterns of activation in post-conditioning startle trials were similar to those in Cue-Only trials, but distinct from those observed in generalized startle trials.

Conclusion: The observation that post-conditioning startle could elicit postural responses more rapidly than those in the Cue-Only trials suggests that aspects of motor programs pertaining to postural reactions could involve the reticular formation of the brainstem [1]. Although further work is necessary, these findings support the potential role of the brainstem in triggering components of directionally-specific postural responses.

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O.7

Effects of initial standing positions before transient floor translation on contingent negative variation of brain potential

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Introduction: We investigated the effects of initial standing positions before transient floor translation on contingent negative variation (CNV) of brain potential [1-3].

Methods: Fourteen subjects were perturbed in a warning (S1)-response stimulus (S2) paradigm with 2.0-s inter-stimulus interval. S2 stimulus was a transient backward translation of the floor in the horizontal plane. Standing position of subjects was represented by position of the center of pressure (CoPy) in the anteroposterior direction, indicated by distance of CoP position from the heel as a percentage of foot length (%FL). Until the onset of perturbation, the subject maintained the following initial standing positions: 1) forward-leaning position (FLP, mean=72.9%FL); 2) quiet standing position (QSP, 41.6%FL); and 3) backward-leaning position (BLP, 31.5%FL). CNV from a Cz electrode was analyzed.

Results: CoPy position during extreme forward leaning was 82.7%FL, and forward peak of CoPy fluctuation with perturbation was 89.2%FL in FLP, 64.9%FL in QSP, and 54.0%FL in BLP. N100 amplitude of early CNV was largest in FLP. Onset of late CNV was earlier in FLP than BLP and QSP. Although no effect of initial position was recognized on peak amplitude of late CNV, the CNV peak latency was earlier in FLP than other conditions and the decrease of the CNV from peak to S2 was larger in FLP and BLP than in QSP.

Conclusions: These results suggest that postural equilibrium with floor translation changes according to initial standing position, and each parameter in early- and late-CNV reflects different aspects of the attention allocation process and/or motor preparation for upcoming perturbation.

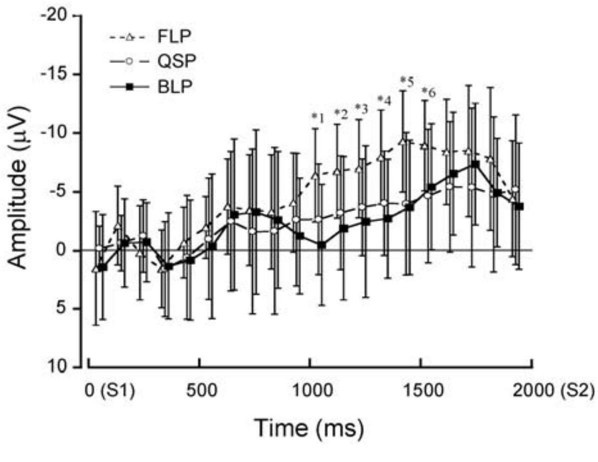

Fig.1 Means and standard deviations of CNV amplitude for every 100 ms. Asterisks indicate a period in which a significant effect of initial position was shown by repeated measure ANOVA. Post-hoc analyses indicated significant differences between FLP and other conditions, except for period *2 where significant difference was indicated only between FLP and BLP conditions (*1: $P < 0.01$; *2: $P < 0.05$; *3: $P < 0.05$; and *4: $P < 0.01$; *5: $P < 0.01$; *6: $P < 0.05$).

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O.8

Spatiotemporal organization of motoneuron activity in the human spinal cord during different gaits

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INTRODUCTION: Even though central pattern generators (CPGs) can provide stereotyped rhythmic activity during fictive locomotion, the motor output in natural conditions is highly adaptable and context-dependent [1-2]. Furthermore, symmetries in locomotor pattern generators can be used to infer or predict neuronal network architectures for different gaits [3]. Here we studied the spatiotemporal organization of motoneuron (MN) activity in the spinal cord during different human gaits as a way to investigate the characteristics of the locomotor circuitry.

METHODS: The electromyographic (EMG) activity patterns in 32 limb and trunk muscles was recorded both ipsilaterally and bilaterally from normal subjects during different gaits including walking; running, backward walking, skipping and stepping in place. We mapped the recorded EMG activity patterns onto the spinal cord [4-6] in approximate rostrocaudal locations of the MN pools. We also performed supplementary statistical analyses of EMG patterns [1]. A special focus was placed on the bilateral coordination.

RESULTS: The activation of MNs tends to be segregated by spinal segment in a gait-specific manner. In particular, sacral and cervical activation timings were clearly gait-dependent. The centre of bilateral MN activity in the lumbosacral enlargement showed two prominent oscillations within one gait cycle for most gaits, and a temporal sequence of activation peaks in the lumbar and sacral spinal cord was also gait dependent. Skipping, a distinct human gait, comprised the features of both walking and running. Swing-related activity constituted an appreciable fraction (>30%) of the total MN activity of leg muscles in all gaits. Locomoting at non-preferred speeds (running and walking at 5 and 9 km/h, respectively) showed noticeable differences relative to preferred speeds. Walking at high non-preferred speeds was accompanied by an 'atypical' locus of activation in the upper lumbar spinal cord during late stance and by a drastically increased activation of lumbosacral segments. The latter findings suggest that the optimal speed of gait transitions may be related to an optimal intensity of the total MN activity. A strikingly similar temporal structure of the motor output was observed during backward walking, despite significant changes in individual EMG activity patterns and in recruitment of the spinal segments.

CONCLUSIONS: The 'pulsatile' nature of the major part of the motor output is consistent with 'drive pulse' rhythmic elements or primitives in the spinal circuitry of animals [7]. The distribution of activity seems to be functionally downstream from the rhythm generation. The results overall support the idea of flexibility and adaptability of spatiotemporal activity in the spinal circuitry with constraints on the temporal functional connectivity of hypothetical pulsatile burst generators. The bilateral coordination of MN activity in the human spinal cord is clearly gait dependent.

ACKNOWLEDGEMENTS: The financial support of Italian Health Ministry, Italian University Ministry (PRIN and FIRB projects), and Italian Space Agency (DCMC grant) is gratefully acknowledged.

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O.9

Markerless sit to stand analysis to predict SPPB scores in elderly people

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INTRODUCTION: Sit-to-Stand transfer (STS) has been widely studied in clinical and rehabilitation contexts: the inability to rise from a seated position is associated with an increased risk of falling in elderly people. Kinematics of this task is usually extracted by using markers applied on the body surface, and *ad hoc* hardware and software. In clinical practice, the qualitative information obtained by visual inspection is commonly accepted as a cheap, quick, and easy to use way of determining subjects' motor skills. In the present contribution, markerless analysis of video sequences captured with a low-cost video camera is performed to extract performance kinematic parameters, and test if they were able to predict scores coming from the Short Physical Performance Battery (SPPB) test [1].

METHODS: 41 healthy elderly subjects (70±9 yrs) were administered the whole SPPB test, and scores from the tests were calculated. Then, they were asked to repeat the STS task 3 times at a self-selected comfortable speed. A digital camera was used to capture the videos (1.4 Mpixel, 25 fps). Translations and rotations of relevant points at the shoulder, waist, knee, and ankle level were estimated by means of a maximum likelihood approach carried out by transforming the video frames in the Gauss-Laguerre domain [2]. Then, a 2D kinematic body model was built to estimate the angle trajectories, namely trunk and leg flexion (i.e. $\alpha(t)$ and $\gamma(t)$) [3]). The duration of each STS phase, minimum values of both $\alpha(t)$ and $\gamma(t)$, and maximum velocities were then calculated from these trajectories. To verify if the extracted parameters were able to predict SPPB scores, regression was done both separately for each parameter and by using a multivariate approach, with SPPB scores as dependent variables.

RESULTS: The analysis of $\alpha(t)$ and $\gamma(t)$ and their maximum velocities shows limited leg mobility and high trunk oscillations (α_{min}=48.5±10.9 deg; γ_{min}=70.9±6.1 deg; $V\alpha_{max}$=76.6±25.9 deg/s; $V\gamma_{max}$=30.4±11.9 deg/s): subjects present a "fully forward" strategy in accordance with published studies on elderly population. No parameter was able alone to reliably predict SPPB scores, whereas multivariate statistics obtained by using all the parameters yielded fair results (residual variance 2.3 SPPB points).

CONCLUSIONS: Parameters extracted from STS manoeuvre kinematics, as estimated by the Gauss-Laguerre markerless approach allowed identifying the different strategies in movement execution in a repeatable yet patient-comfortable way. At the same time, the results obtained in terms of their ability to predict the overall scores from the SPPB test were just fair, thus outlining the need to objectively monitor not only STS, but also the other SPPB motor tasks (i.e. balance and gait).

ACKNOWLEDGEMENTS: this work has been partially funded by the ministry of the national government for education, university, and research.

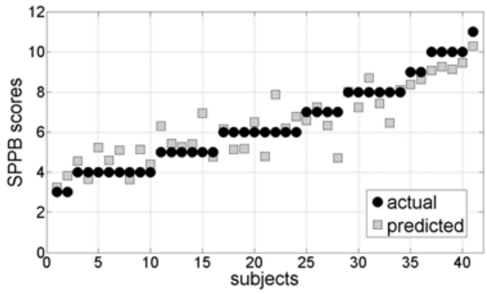

Fig. 1. SPPB scores as fitted by multivariate statistics (actual scores in black circles)

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O.10

3D gait analysis using wearable 6D IMU on shoe

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INTRODUCTION: Recently, a number of studies have shown that miniature body-worn inertial sensors can be used for temporal and spatial gait analysis. 2D Gait analysis by means of inertial sensors was introduced on lower limbs [1] and then on foot [2]. Use of 3D sensors was introduced in [3] for drop-foot stimulation. The aim of this study was to provide a wearable inertial system attached to the shoe providing accurately spatio-temporal gait parameters and the 3D trajectory of the foot during unconstraint walking involving different pathways.

METHODS: A 6D Inertial Measuring Unit (IMU) including tri-axial accelerometer and tri-axial gyroscope was attached on the rear part of the shoe. Key temporal events of each gait cycle were detected using 6D signals. Static period before gait initiation was used to know initial orientation, and then 3D orientation quaternion was incrementally computed with gyroscope signals and re-aligned at each static period through accelerometers. Therefore, IMU was virtually aligned to compute 3D accelerations in fixed frame. 3D velocities and displacements were computed by integration of accelerations and by considering some biomechanical constraints to avoid error accumulation. More than 90 gait cycles with various velocities were recorded using a motion capture system as reference, including 7 VICON cameras and 3 markers attached to the 6D IMU. Different walking trajectories including turning were tested.

RESULTS: Results are given for overall gait cycles including transition steps and turns. 3D Orientation was determined with 2.4° RMS error. Accuracy±Precision obtained for step length, foot clearance and stride velocity were respectively 1.6±4.9cm, 0.3±0.8cm and 1.3±4.2cm/s. Figure 1 Compares the foot trajectory based on 6D IMU system with the reference system.

CONCLUSIONS: The results obtained so far showed that the 6D IMU attached on foot were more precise than previous technique using 2D gait analysis. The proposed method has a great potential in clinical evaluation of gait. Moreover it doesn't require any per-subject calibration and works automatically with any gait path. Main contributions are new parameters, such as 3D spatial trajectory and orientation. The system will be used in the framework of SMILING project aiming at counteracting falls in the elderly by challenging the patient to solve new motor problems in real time.

ACKNOWLEDGEMENTS: The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 215493-ICT - SMILING project.

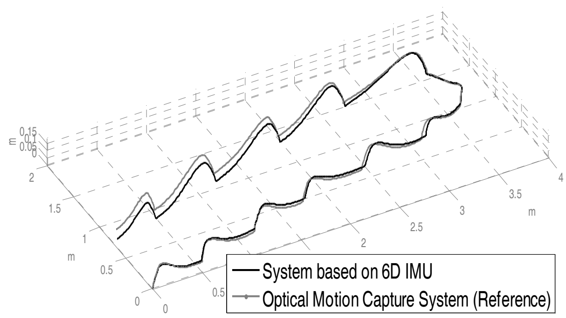

Fig.1 3D Foot trajectory during gait initiation, steady state walking and turning.

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O.11

Automated biofeedback assistance for freezing of gait in patients with Parkinson's disease

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INTRODUCTION: Freezing of gait (FOG) is a disabling gait disturbance commonly seen in patients with advanced Parkinson's disease (PD). It has been suggested that external cuing provided in a timely fashion may help the patient to negotiate the FOG episode and to resume functional walking. In recent years, the use of context aware wearable devices for medical purposes has been gradually spreading. We tested the idea that a wearable device that recognizes, in real-time, the occurrence of a FOG episode and provides auditory cueing may be used to "break" the freezing and reduce its impact on the mobility of patients with PD.

METHODS: 10 PD patients (66.5±4.8 y; H&Y in "ON";2.7±0.6) with a history of FOG were studied. 8 patients were examined in the "OFF" state (>12h from last medication uptake) and 2 patients who experience FOG also during the "ON" medication cycle were examined in the "ON" state. Patients wore a miniature 3D accelerometer (27x 4x15 mm^3, 25 grams) attached to one of their ankles. Time series of acceleration were transmitted (64Hz) wirelessly to a wearable device (132x82x30 mm^3, 231 grams) placed on the trunk for real-time identification of FOG (using an algorithm based on a set of frequency content criteria). Earphones placed around the subject's neck and connected to the wearable device produced a 1 Hz ticking sound whenever an episode was identified and lasted 3 s after the subject resumed walking. The subjects walked twice for about 10 min in paths representative of normal daily walking (straight line, turning, and moving around rooms) with and without the earphones connected. Real time annotation and simultaneous video taping were used to determine the number of FOG episodes. Self-report of patient satisfaction also determined using a standardized form.

RESULTS: 8 patients exhibited FOG in the lab. 96.2% of the identified FOG episodes (n=237) were detected online by the wearable device and in all of these cases the auditory cuing started to operate. The 'technological' sensitivity and specificity of the device were 73.1% sensitivity and 81.6%, respectively (based on 0.5 sec moving window). Post-hoc optimization analysis suggested that these figures could have been 88.6% and 92.8%, respectively; if the device would have been 'calibrated' for each of the patients based on their gait characteristics (Figure 1).

CONCLUSIONS: Wearable devices can measure leg movements with acceleration sensors to identify freezing of gait in real-time and produce a response that alleviates this paroxysmal gait disturbance common to patients with Parkinson's disease.

ACKNOWLEDGEMENTS: This work is part of the DAPHNet project, 'Dynamic Analysis of Physiological Networks', supported by the European 6th Framework Program, Grant No. 018474-2.

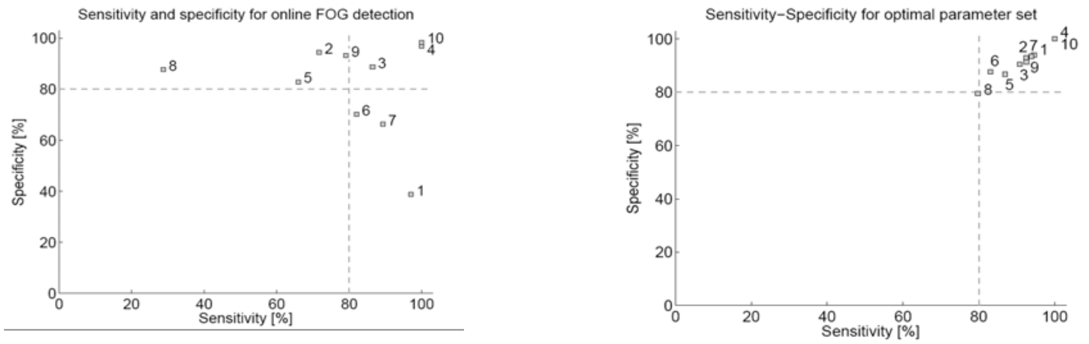

Fig.1 Sensitivity and specificity plots for online automated detection of FOG for all individuals prior (left) and post (right) adjusting algorithm parameters based on individual gait characteristics. Each point denotes one subject.

O.12

Differentiating malingering patients from healthy controls, unilateral vestibular loss patients and whiplash patients

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INTRODUCTION: Differentiating malingering balance disorder patients from those with organic balance disorders is difficult and costly. We examined whether objective criteria based on stance and gait posturography can aid this task

METHODS: Trunk sway angle and angular velocity in the roll and pitch plane was measured with a SwayStar™ system during several stance and gait tasks in 18 patients suspected of malingering. Their data was compared with that of 20 patients suffering unilateral vestibular loss 3 months earlier, 20 patients with documented whiplash injuries, and 35 healthy controls. Stepwise discriminant analysis was used to determine variables and criteria which best differentiate malingering patients.

RESULTS: Classification results appeared best for criteria or variables based on 90% sway values (excluding the upper and lower 5% of sway) and ranged from 72% (for all four groups) to 96% (malingering versus controls). Criteria that were important for this discrimination were: the difference in roll velocity during standing with eyes closed on foam and firm surface; pitch velocity for standing with eyes open on firm surface; and the difference in pitch velocity during tandem steps and standing on 1 leg. When using sway variables for the differentiation, roll angle for standing on 1 leg was needed in addition to most variables used in the criteria.

CONCLUSIONS: Discriminating suspected malingering balance disorder patients is possible by using criteria based on objectively measured trunk sway during several stance and gait tasks.

O.13

Differentiation of young and older adult stair climbing gait using principal component analysis

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INTRODUCTION: Gait analysis is a non-invasive tool that can identify and define biomechanical responses to age-related changes of the musculoskeletal system. Principal component analysis (PCA) has been used to reduce the volume of gait data and to identify the difference between populations. This approach has not been used on stair climbing gait data. Our objective was to use PCA to determine the major gait differences between young and older adults while negotiating stairs.

METHODS: The knee joint mechanics of 30 healthy young adults (23.9 ± 2.63 yrs) and 32 healthy older adults (65.5 ± 5.01 yrs) were analyzed while they ascended a specially constructed 4-step staircase. The three-dimensional net knee joint forces, moments and angles were calculated using typical inverse dynamics. Principal component analysis reduced the complexity of these gait waveforms to 16 variables. The principal component scores (PCs) of the net knee joint force, moment and angle waveforms were analyzed for group differences using analysis of variance. A stepwise discriminant function analysis determined which variables differentiated the two groups.

RESULTS: The number of PCs retained for analysis was chosen using a 90% trace criterion (Table 1). Four of the PCs were optimal in defining a discriminant model of the waveform data, correctly classifying 96.7% of the original group (Table 2). In order of their discriminatory ability these were: the magnitude of the adduction moment during stance; the magnitude of the knee flexion moment from late swing through to end of stance; the magnitude of the knee distal-proximal force during late stance; and the fourth PCs in the discriminant model had two features about it: 1) phase shift during early stance; 2) the magnitude of the knee flexion moment during late stance.

CONCLUSIONS: The PCA and discriminant function analysis applied in this investigation identified gait pattern differences between young and older adults and ranked the relative ability of these features to differentiate between the two groups. Identification of stair gait pattern differences between young and older adults could help in understanding age-related changes associated in the performance of the locomotor task of stair climbing.

	Knee LM Force	Knee Ad-duction Moment	Knee Flexion Angle	Knee Ad-duction Angle	Knee Internal Rota-tion Angle	Knee Ad-duction Moment	Knee Flexion Moment	Knee Internal Rota-tion Moment
Variation Explai-ned (%)	93.08	90.91	93.47	91.42	93.47	94.07	92.24	93.97
Number of PCs	2	1	3	1	3	1	3	2

Table 1 - Principal Component Models

PCs placed in the discriminant model	% of original group correctly classified
Knee Adduction Moment PC1	90.2
Knee Adduction Moment PC1 Knee Flexion Moment PC2	93.4
Knee Adduction Moment PC1 Knee Flexion Moment PC2 Knee DP Force PC2	93.4
Knee Adduction Moment PC1 Knee Flexion Moment PC2 Knee DP Force PC2 Knee Flexion Angle PC3	96.7

Table 2 - Discriminant Model

O.14

Validation of a new instrumented ramp to assess ambulation while ascending and descending a slope.

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INTRODUCTION: Some studies have assessed the locomotor adaptations during stairs or slopes negotiation [1-4]. However, their muscle utilization patterns (EMG) and biomechanical requirements (moments and powers, etc.) have apparently never been compared across the same subjects. This is needed to better guide home adaptations and locomotion recovery. Our project aims to provide clinicians with such comparison using results obtained from gait analyses performed in a laboratory equipped with kinematic recorder, EMG sensors, instrumented stairs (with force platforms in two steps) and instrumented ramp with a 8.5° or 15% slope (with two force platforms in the centre) (Fig. 1). The goal of this study was to validate the mechanical behaviour of the instrumented ramp to make sure that the forces recorded when walking and analysed at 60 Hz match the amplitude and the instant of the real exerted forces.

METHODS: The exact measurement of frequency magnitude and phase of the ground reaction forces depend on the vibration characteristics of the AMTI® platforms set up on a specific support (i.e. natural frequency and damping) and of the frequency of the signals of interest of the task itself: i.e. the walking [7]. Rapid impacts onto the platforms support and the inclined plane, in 10 various locations were repeated 3 times, and enabled the estimation of the damping coefficient "ζ" and of the natural frequency "ν_n" through fast Fourier transformation analysis. During walking, the highest frequency of the signal of interest "ν_i", i.e. the highest frequency covering 90% of the signal power spectrum, was obtained when a healthy subject ambulated up and down the slope on several occasions. The errors on steady-state frequency amplitude "E" (%) and on the delay due to damping "dt" (s) were calculated using standard equations (Fig. 2).

RESULTS: Both platforms had the same characteristics: ν_n = 148 Hz et ζ = 0.07. The highest frequency of the walking signal of interest was ν_i = 4 Hz. Therefore, E and dt were respectively equal to 0.07% and 0.004 ms which are negligible compared to the manufacturer's given error (0.2%) and to the 17 ms period of the 60 Hz analysis.

CONCLUSIONS: The validity of the new instrumented ramp is confirmed. The reaction forces exerted on the two embedded platforms were recorded accurately and without any delay. The next step will be to compare the mechanical requirements of slope and stairs ascents and descents within a group of healthy individuals.

ACKNOWLEDGEMENTS: Special thanks are extended to the Lindsay Foundation for its financial support. F. Chedevergne holds a post-doctoral scholarship from the Quebec Rehabilitation Research Network. S. Nadeau has a senior scientist salary from the Fonds de la Recherche en Santé du Québec.

Fig.1 Instrumented ramp negotiated by a walking healthy individual

$$E = \left(1 - \frac{1}{\sqrt{\left[1-\left(\frac{\nu_i}{\nu_n}\right)^2\right]^2 + \left[2\zeta\left(\frac{\nu_i}{\nu_n}\right)\right]^2}}\right)*100$$

$$dt = \frac{1}{\nu_n * 2 * \Pi} * \arctan \frac{2*\zeta*\frac{\nu_i}{\nu_n}}{1-\left(\frac{\nu_i}{\nu_n}\right)^2}$$

Fig.2 Equations used for the steady-state error (E) and the delay of measurement (dt).

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O.15

Portable system for the linear and non-linear re-calibration of force platform

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INTRODUCTION: Force platforms (FPs) are routinely used in human movement analysis. Over time, the instrument sensitivity may change and cause undesired crosstalk between the output variables, leading to a lack of accuracy [1]. Further, a non-linear behaviour can be present, mainly due to the bending under load of the FP top plate [2]. We propose here a system that re-calibrates the FP and, at the same time, quantifies and compensates for the force platform non-linearity. The system was experimentally tested on 4 commercial FPs, and its effectiveness was verified by quantifying the FPs accuracy in the COP measurement, before and after re-calibration.

METHODS: The system (Fig. 1) is mainly composed by a high-precision triaxial load cell, positioned in known positions on the FP surface and then loaded by a subject that generates a 3D time-varying force. By this system, the re-calibration process uses forces in the usual range of posture and gait tests. The algorithm estimates the local or global, linear or non-linear re-calibration matrix of the FP through a least-squares optimization.

RESULTS: Table 1 shows the COP accuracy before and after the re-calibration process, for the 4 tested FPs. In the following, the FP manufacturers are omitted, since no comparison between the manufacturers was intended. The errors (mean±std) are expressed in mm.

CONCLUSIONS: The increased accuracy in rows (2) and (3), with respect to row (1), was due to the linear re-calibration of the FP output signals. The better results of local re-calibrations (3) with respect to global re-calibrations (2) were due to the non-linear phenomena that a local re-calibration may better compensate for, since it describes the behavior of the FP on a reduced FP area. The non-linear, global, re-calibration method (4) ensured similar results as local, linear re-calibration (3), proving its suitability to well re-calibrate the FPs, also compensating their non-linearity due to the bending of the top plate. This system can be therefore considered as effective to re-calibrate the FPs.

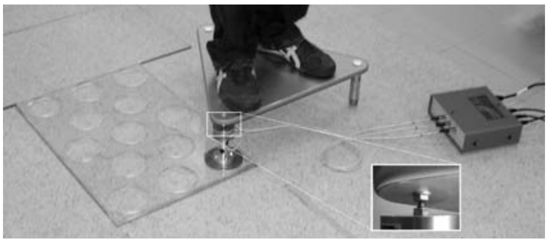

Fig.1 The re-calibration system

COP accuracy	FP #1	FP #2	FP #3	FP #4
(1)Initial accuracy	2.3±1.4	2.6±1.5	12±4.3	14±2.5
(2)Linear global	1.1±0.6	1.8±1.1	1.0±0.6	3.2±1.1
(3)Linear local	0.7±0.4	0.8±0.5	0.5±0.3	2.0±1.2
(4)Non-linear global	0.7±0.4	0.6±0.2	0.5±0.2	2.3±1.3

Table 1 COP accuracy results [mm]

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O.16

The development of adaptation: How infants and adults modify their walking steps

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INTRODUCTION: Previous research has shown that both infants and adults adapt their walking patterns to changes in the environment, such as slants (Gill, Adolph, & Vereijken, in press), or when carrying loads (Garciaguirre, Adolph, & Shrout, 2007; Vereijken, Pedersen, & Størksen, manuscript under review). However, due to differences in body characteristics, skill levels, and experience, infants and adults cope with change differently. In this study, we presented a novel challenge to infants and adults, walking with one normal and one thick sole on their shoes, and investigated how the process of adaptation unfolded in both groups at multiple time scales.

METHODS: Eighteen 14-month-old infants and 19 adults (mean age 22.1 yrs, *SD* 4.9) participated. Special shoes were constructed with one normal thin sole and one modified thick sole, 2.6 cm for infant shoes and 4.4 cm for adult shoes. Participants walked over an electronic gait carpet (GAITRite) 10 times in each of 4 conditions: baseline (two thin soles), platform (one thick, one thin sole), practice platform (one thick, one thin sole), and return baseline (two thin soles). In between the two platform conditions, participants walked around the laboratory freely for 15 minutes to extend their practice with the modified shoes. We coded gait irregularities from video (falls, trips, stops, double steps, cross steps), and calculated normalized step length, step length variability (coefficient of variation), and walking speed.

RESULTS: Infants had frequent gait irregularities in all conditions, averaging 18.7 per infant, with most irregularities occurring in the platform and return conditions. Compared to baseline, infants reduced step lengths of both feet in the platform, practice, and return conditions, they reduced walking speed in the platform condition, and showed higher step length variability in platform and return conditions. Adults, on the other hand, showed few gait irregularities, only 3 instances across all conditions and trials. In the two platform conditions, adults reduced step length in the leg wearing the thin sole while slightly increasing step length in the leg wearing the thick sole. Furthermore, they maintained walking speed and step length variability at similar levels across conditions. Both infants and adults adapted their gait immediately in the first few steps of the first trial in a new condition, but whereas adults converged quickly on a single solution, infants' adaptations remained variable both within and across trials.

CONCLUSIONS: Both infants and adults adapted their gait instantly when wearing modified shoes, but they modified their gait in different ways. Infants showed many gait irregularities and several gait changes that occurred mostly when shifting from equal to unequal soles or back. Adults showed virtually no gait irregularities and consistent gait changes when wearing unequal soles, and switched back to normal gait when wearing equal soles. Adults' long experience with walking may have allowed them to maintain gait with consistent adaptation in the face of novel challenges. Fourteen-month-old infants, on the other hand, have limited walking experience and are not proficient walkers yet, still displaying high levels of variability in baseline gait. Consequently, they did not find a single adaptive solution like the adults, but displayed higher variability in their adaptation to a novel challenge.

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O.17

Visual control of rapid limb movements evoked by unpredictable postural perturbation

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INTRODUCTION: Visuospatial information (VSI) about the surrounding environment is required for the control of balance reactions that involve rapid limb movement toward handholds or step locations [1,2]. Although the visual control of volitional limb movements has been studied extensively [3,4], relatively little has been known about the visual control of perturbation-evoked limb reactions. To prevent falls, these reactions must be initiated and executed very rapidly, while maintaining sufficient accuracy to accommodate environmental constraints on limb trajectory [1,2]. This work aimed to determine the degree to which the CNS relies on VSI acquired and stored prior to perturbation onset (PO) to guide perturbation-evoked limb movement, whether online visual control of the limb movement is necessary or sufficient, and the extent to which peripheral vision can be used to guide the limb movement.

METHODS: This work comprises three stepping studies and four grasping studies (total of more than 80 healthy young-adult subjects). Two complementary approaches were adopted: 1) recording the natural gaze behavior associated with the limb reactions, and 2) probing the visual control mechanisms by imposing spatial and/or temporal constraints on visual inputs. The latter involved using: pinhole goggles to block peripheral vision; liquid-crystal goggles to occlude vision either before or after PO (forcing reliance on online or stored VSI, respectively); and voluntary fixation of a central visual target (to force reliance on peripheral vision). Reactions were evoked by sudden unpredictable translation of large motion platforms (2x2m, 2x6m) on which the subjects stood or walked. Constraints on limb movement (step obstacles, step/grasp targets) were either static or were varied unpredictably by means of motor-driven obstacle and handhold movers. Motion analysis, EMG and force plates were used to characterize the limb reactions; a head-mounted eye tracker recorded gaze direction.

RESULTS: Online visual fixation of the limb or movement target was not required to execute an effective step or grasp reaction. Subjects typically did not look at the foot or landing site when stepping, even when obstacles or step targets increased demands for accuracy or when multiple obstacles changed position unpredictably prior to PO. Similarly, subjects never looked directly at a handrail when grasping it in reaction to an unexpected perturbation applied as they walked for the first time in an unfamiliar environment. When forced to use online (rather than stored) VSI to guide the step-foot between obstacles, subjects were much more likely to make trajectory or limb-selection errors. Forced reliance on peripheral vision did not impair ability to achieve a functional grasp of a small handhold that changed position unpredictably prior to PO, but did increase movement time significantly (by ~75ms) when the handhold was located in the more extreme periphery (i.e. visual angle of 40 degrees).

CONCLUSIONS: Results from these studies of healthy young adults suggest that the CNS prioritizes rapid initiation of the reaction, and is able to achieve the required level of accuracy by utilizing VSI stored proactively (prior to PO) and/or online feedback from the peripheral visual field.

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O.18

Learning postural adjustments as a skill in the context of a volitional task: evidence for a memory consolidation phase

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INTRODUCTION: Postural adjustments are essential for voluntary movement as they provide the foundation for motor performance. Yet the time-course of learning postural adjustments, the specificity of learning and the ability to effectively retain this knowledge are not well known. The objective of this research was to study the characteristics of the acquisition of postural control skills in healthy adults within a virtual environment (VE).

METHODS: Eight healthy young adults, aged 20-40 years (mean ± SD = 28.6 ± 2.7), performed a single training session in a VE in which maintenance of balance on a moving platform according to a given road scenario, as well as a secondary visual target reaching task were required, in repeated runs. Balance performance and movement time (MT) of the upper extremity (time between the appearance of the moving target to its interception) were assessed during training and additional assessments were performed at 24 hours and 4 weeks post-training.

RESULTS: The results showed that the Centre of Pressure (CoP) displacement decreased during the training session (P=0.004) and continued to decrease 24 hours post-training (P=0.029) (i.e., a delayed gain in skill) (fig. 1A). The gains were robustly maintained by 4 (p=0.138) and increased by 12 (p=0.003) weeks post training. MT of both the left and the right hand decreased significantly (p=0.001 and 0.01), during the training session. There was no significant decrease on the second day (fig 1B) or at 4 and 12 weeks post training. New learning occurred when the secondary task was made more demanding but not when the virtual road was experienced without the secondary task or with eyes closed.

CONCLUSIONS: A single training session in a VE designed to elicit balance maintenance was sufficient to trigger a learning process of balance control resulting in immediate gains, delayed gains and robust retention. The time-course (including the expression of delayed gains, i.e., a consolidation phase) and magnitude of the learning process of postural adjustments as manifested by CoP displacement appears to be similar to that which takes place during volitional manual task learning. The balance control gains were not altogether independent of the secondary task (context). The learning process of the secondary task, as manifested by the decrease in MT, was not sufficient, and more repetitions may be needed during training in order to trigger delayed gains.

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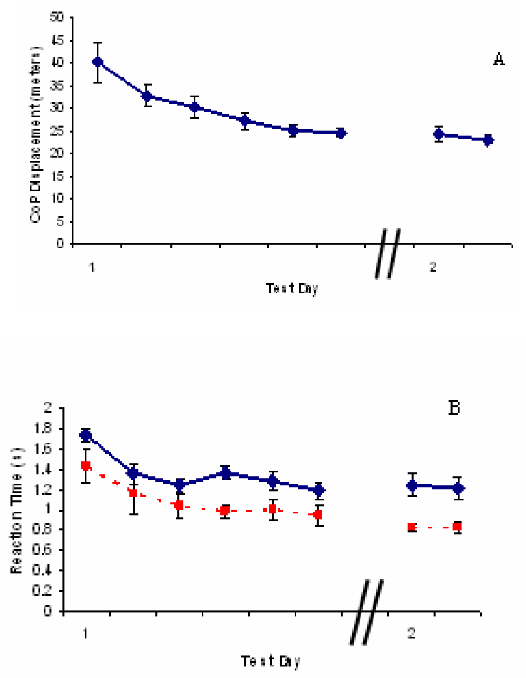

Fig 1 (A) mean CoP displacement and (B) Movement time of the right upper extremity (solid lines) and the left upper extremity (dashed lines) in the trained condition as a function of the number of road scenario iterations during the training session and at 24 hours (Day 2) post-training.

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O.19

Impact of cognition on motor control and adaptation to novel slip induced in walking

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INTRODUCTION: A person's awareness of danger to slip can induce a cautious gait pattern. This study examined (1) whether such awareness alone, or even with cognitive training, could successfully alter recovery outcome to a *novel* slip on the right side, and (2) whether, after motor training with repeated-slip exposure on the ipsilateral (right) side, the same awareness could alter recovery outcome to a *novel* slip on the contralateral side.

METHODS: *Experiment 1:* Thirty-two healthy young subjects were exposed to a novel right-side slip. Twelve did not know where, when, and how a slip would occur (NOCOG). Ten received spatial information from watching videos and slides demonstrating where and how the slip would occur and how people adapted to repeated-slip exposure (COG_CON1). Ten received spatial and temporal information on where (exact location) and when (exact trial) the slip would occur (COG_CON2). *Experiment 2:* Twenty-four healthy young subjects were exposed to repeated right-side slips before a novel left slip. Twelve, all from NOCOG group, did not know where, when, and how a left slip would occur. The other 12 were aware of the timing and location of the novel left slip (COG_CON3). Gait stability was obtained as the shortest distance between the measured center of mass (COM) state (position & velocity) & the mathematically predicted threshold for backward loss of balance (BLOB) at pre-slip touchdown of slipping & post-slip liftoff of contralateral limb.

RESULTS: Results from *Experiment 1* indicated that although awareness and cognitive training could improve performance, that the COG_CON1 and COG_CON2 had significantly greater stability than that on the novel slip of the NOCOG group. Such improvements in themselves, however, were insufficient to reach the threshold that all subjects in the NOCOG, COG_CON1 and COG_CON2 groups still experienced balance loss. Results from *Experiment 2* indicated that both the NOCOG and COG_CON3 groups adapted similarly to reduce the incidence of backward loss of balance (BLOB) from 100% to 0% with repeated-slip training on the right side. Upon the novel left slip, the COG_CON3 group's BLOB incidence was significantly lower than that of the NOCOG (55% versus 92%, respectively, $p < 0.05$). This was attributed to the COG_CON3 group's significantly greater pre- and post-slip stability and its better control of the slipping foot than those upon its first right slip ($p < 0.05$) and than those upon the NOCOG group's novel left slip ($p > 0.05$).

CONCLUSIONS: The results suggest that cognition facilitates application of motor training related skill acquisition to a novel situation as demonstrated on the contralateral side in the present study. Further it is suggested that heightened awareness, or even cognitive training, in itself is insufficient to replace the motor training related skill acquisition and may still require establishment of an adaptive motor program in the CNS in order to substantially induce behavioral improvements to resist slip-related fall.

O.20

Analysis of power exertion for lifting the CoM during mobility related activities in daily life

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INTRODUCTION: The speed with which muscular forces produce movements of body segments is one of the determinants of the successful performance of sportive activities. However, also the safe performance of mobility related activities in daily life (such as rising from a chair, walking and stair climbing) depends on muscle power. Usually power analyses are restricted to a laboratory, but possibly body-fixed-sensors (BFS) may be used to develop methods for assessing muscle strength or power during daily activities [cf. 1]. Since measures of Sit-to-Stand (STS) performance are important indicators of overall functioning and balance performance in older persons, this study analysed power exertion during STS based on laboratory methods as well as BFS.

METHODS: Five healthy young (21-44 yr) and 12 healthy older (70-79 yr) subjects performed STS movements while data were measured with force-plates underneath chair and feet and motion sensors attached to different locations on the upper and lower trunk. Data were obtained after subjects were given different instructions for STS performance. Force-plate data were used to determine the timing of STS movements and the vertical power for lifting the body's centre of mass (CoM) from a sitting to a standing position. Data of 3D hybrid motion sensors [2] were used to determine vertical accelerations and power.

RESULTS: In the young subjects, mean movement durations of STS performance varied between 0.88-2.52 s. Mean STS duration of the older subjects was close to mean STS duration of young subjects at their preferred speed, i.e. 1.28 versus 1.25 s. A wide range of CoM accelerations and peak power values were obtained; in the younger subjects peak powers ranged between 185-1364 Watt, in the older subjects this range was 209-873 Watt. The comparison of sensor-based power estimations with power calculated from force-plate data demonstrated that fair to excellent estimations of power can be obtained from vertical accelerations of trunk segments. The best approximation of peak power was obtained by a weighted combination of data from motion sensors at different trunk locations (cf. fig. 1). Results of the older subjects were consistent with those of the young subjects performing slow, normal and fast STS movements.

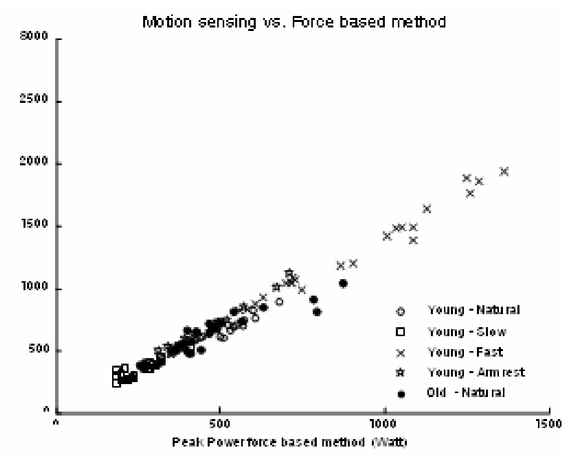

Fig.1 Motion sensing vs. Force based method

CONCLUSIONS: Power can be estimated based on BFS. The presented approach is relevant for mobility assessment in older people. Similar approaches for assessing power may be developed for other mobility related activities, such as stair walking, or sports related activities such as jumping.

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O.21

Active stiffness and damping increase with age in postural control

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INTRODUCTION: Upright balance is believed to be maintained through active and passive mechanisms, both of which have been shown to be impacted by aging [1-2].

METHODS: We investigated the effect of aging on postural control by fitting a previously developed model [3] with active and passive parameters to body sway data obtained from ten young (24 ± 3 y) and seven older (75 ± 5 y) adults. Subjects were exposed during eyes-closed stance to perturbations consisting of pseudorandom floor tilts, pseudorandom/pulsed galvanic vestibular stimulation (GVS), or both perturbations together, to evoke medial-lateral body sway. Some trials included dual-task conditions as well, involving choice reaction time and other information processing tasks.

RESULTS: We report results here on a subset of trials, corresponding to the floor tilt condition only, without dual tasks. A least-squares fit of the postural control model to the data found significantly larger active stiffness and damping parameters in the older adults. Specifically, the active stiffness in the older adult group was 1225 ± 299 [N·m/rad] versus 898 ± 215 in the young ($p<0.01$). The active damping was 370 ± 86 [N·m·s/rad] in the older adult group versus 288 ± 71 in the young ($p<0.05$). These differences remained significant even after normalizing the stiffness and damping to account for different body sizes between the young and older adult groups. No age effect was found on the (unnormalized) passive stiffness and damping, however the normalized passive stiffness was significantly larger ($p<0.02$) in the older adults. In general, and consistent with previous studies [3], the magnitude of the active parameters was about ten times that of the respective passive parameters, indicating that the passive stiffness and damping contribute relatively little to postural control in response to platform perturbations. Using the model-fit parameter values, simulations of the impulse response of the postural control model were made, which showed that increasing stiffness without a concurrent increase in damping is detrimental to the stability, in that there were larger oscillations in sway that took longer to die away (Fig. 1). Stability is improved if stiffness and damping are increased in adequate proportions.

CONCLUSIONS: This study points out that as we age, there is a modulation of the overall impedance (stiffness and damping) and not only of the stiffness for postural control.

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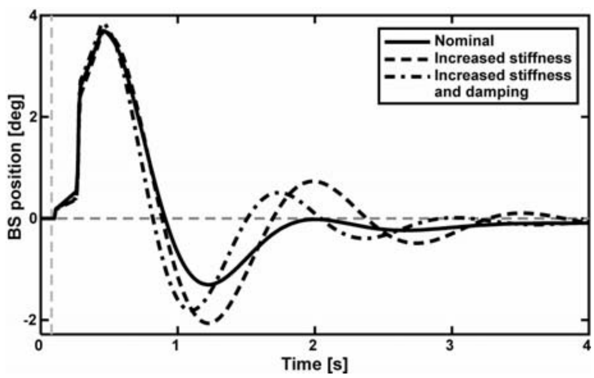

Fig.1 Plots of the impulse response of the postural control model for nominal values of stiffness and damping in the young population (solid curve), versus increased stiffness only (dashed curve), versus increased stiffness and damping (dash-dot curve). Note that peak-to-peak oscillations are greatest for increased stiffness alone.

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O.22

What is the feedback time-delay and extent of linear time-invariant control when subjects manually control stable and unstable loads?

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INTRODUCTION: Upright balance is commonly described using linear-time-invariant (LTI) models. When platform translations are applied, this approach captures the majority of the stimulus-response behavior [1]. In such models, the feedback time-delay represents the position of balance in the motor-control hierarchy. The extent of LTI control illuminates the automaticity of the control process. There is recent, evidence, that quiet standing balance shares similarities with visuo-manual compensatory tracking [2,3]. Thus studying visuo-manual tracking may add insight to understanding the nature of quiet standing.

METHODS: Using non-parametric analysis, we measured the feedback delay, extent of LTI control and visuo-motor transfer function in six randomly disturbed, visuo-manual compensatory tracking tasks analogous to standing with small mechanical perturbations and purely visual information.

RESULTS: The delay depended primarily on load order (2^{nd}: 220±30, 1^{st}: 124±20 ms), and secondarily on visual magnification (extent 2^{nd}: 34, 1^{st}: 8 ms) and was unaffected by load stability. LTI control explained 1^{st} order and stable loads relatively well. For unstable (85% passive stabilisation) 2^{nd} order loads, LTI control accounted for 40% of manual output at 0.1 Hz decreasing below 10% as frequency increased through the important 1-3 Hz region where manual power and visuo-motor gain are high.

CONCLUSIONS: Visual control of unstable 2^{nd} order loads incurs substantial feedback delays and the control process will not be LTI. These features do not result from exclusive use of visual inputs because we found much shorter delays and a greater degree of LTI control when subjects visually controlled a 1^{st} order load. Rather, these results suggest that delay and variability are inevitable when more flexible, intentional mechanisms are required to control 2^{nd} order unstable loads. The high variability of quiet standing, and movement generally, may be indicative of flexible, variable delay, intentional mechanisms rather than the automatic LTI responses usually reported in response to large perturbations.

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O.23

The effect of long distance walking on plantar pressure distribution

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INTRODUCTION: Many long distance walkers develop foot damage and complaints. How this affects plantar pressure distribution is unknown however. Intense running significantly increases peak pressure and relative impulse under the forefoot during walking [1] but the effects of long-distance walking may be very different. Therefore, the aim of this study was to investigate the influence of long distance walking on plantar pressure distribution.

METHODS: 62 participants of the International Four Day Marches of Nijmegen (IFDM) with no prior history of foot complaints participated in this study. All female (N = 32) and male (N = 30) participants walked 40 and 50 km per day, respectively. Plantar pressure was measured when walking over a pressure plate (Rsscan International Belgium) three times per foot. Measurements were done one day before the IFDM (baseline) and each day after finishing the walking. The normalization method of Keijsers et al. [2] was used to calculate mean plantar pressure distribution per sensor of each foot per measurement day. The change of plantar pressure distribution during the IFDM was calculated by subtracting the baseline plantar pressure per sensor from the plantar pressure obtained after finishing each walking day.

RESULTS: After 4 days of walking, the plantar pressure under the distal part of the fifth ray and the heel was significantly increased. Plantar pressure under all toes and the first metatarsal head was significantly decreased. These changes in plantar pressure occurred already at the end of the first day (figure 1). Contact time increased slightly from 629

(+/- 45) ms at baseline to 651 (+/-68) ms at day one and 665 (+/- 66) ms at day four.

CONCLUSIONS: The short-term adjustment to long-distance walking is a decreased loading of the forefoot and increased loading on the lateral side of the foot. At later stages, there was more heel loading in the fatigued feet. It is argued that these changes reflect avoidance of loading of those parts of the foot that are most vulnerable to damage due to overloading. The changes in plantar pressure pattern are due to a different loading and could only be minimally affected by the slight increase in contact time.

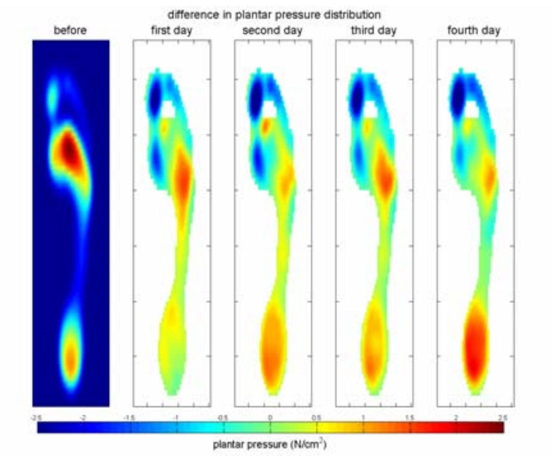

Fig.1. Changes of plantar pressure distribution when walking the IFDM

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O.24

Effects of concurrent spatial and categorical cognitive tasks on the performance of a continuous postural alignment task

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INTRODUCTION: Performing cognitive tasks during unperturbed stance has resulted in increased sway in some studies, and reduced sway in others [1]. The former result is interpreted as destabilization due to competition for common information-processing resources, but the latter result poses problems for this view. It has been suggested that this variety of results arises because the relation between levels of sway and posture control is under-constrained in unperturbed quiet stance. Here, we contrasted the effect of cognitive load on sway in quiet stance against performance in a continuous postural alignment task. We expected that engaging posture control in an explicit precision task (beyond the usual quiet standing or standing as still as possible) would attenuate or eliminate any changes in levels of sway due to addition of cognitive load per se.

METHODS: In Exp 1, 20 undergraduates (7 male, 13 female) stood in canonical stance and performed either a spatial or categorical memory task or no task. In the spatial task, they answered questions about locations of campus buildings (e.g., “You are standing outside the library, looking at the engineering building. The fact that the humanities building is to your right is true/false.”). In the categorical task, they responded to questions such as: “Students who study literature receive an arts degree. The fact that ecology students receive an arts degree is true/false.” The questions were auditorily presented, and accuracy and RT were recorded via button presses on a handheld mouse. Sway was measured at 60Hz from the hip and head using a magnetic tracker. As a control for Exp 2, participants wore a blank HMD that blocked their vision. Exp 2 was identical except that the HMD screen presented two apparently earth-fixed crosshairs (1.2 cm height and width) at 1m and 2m distances from the participant along their line of sight. Tracking head-motion at 60 Hz was used to achieve this effect. In all task conditions, participants (11 male, 9 female) were asked to minimize the relative motion between the crosshairs as it appeared to them. They could achieve this by controlling their ML sway to reduce parallax. Sway measures were moving-window standard deviation and RMS drift (1s window) [2].

RESULTS: In both experiments, accuracy was equally high (above 85%), but the spatial task had longer RT ($p<.05$), suggesting higher cognitive load. In Exp 1, ML sway increased for both tasks relative to no task ($p<.05$), but did not differ between tasks. In Exp 2, ML sway did not differ between no task and categorical task, and was actually *lower* than either in the spatial task condition ($p<.05$). Exp1 is consistent with a resource-competition account, but Exp 2 is not. As expected, adding cognitive load did not increase sway when posture control was engaged in a precise sensorimotor task. The surprising result was the reduction of ML sway (i.e., enhanced performance in the postural alignment task) while performing the harder spatial memory task.

CONCLUSIONS: Our results underscore, first, that engaging posture control in a precise sensorimotor task (beyond quiet standing or standing still) may alter the effects that various types of cognitive load has on sway. Second, the fact that a spatial memory task accompanied better performance in the postural alignment task (itself a spatial task), rather than competing for the same pool of specialized or general information-processing resources, suggests that further study should go beyond resource accounts and explore other aspects of dual-tasking such as compatibility and alignment of task spaces [2].

ACKNOWLEDGEMENTS: Funded by ESRC grant RES-000-22-2248.

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O.25

Nature of the kinematic cues underlying the perception of emotions during human gait

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INTRODUCTION: Perception of emotion from observed whole body movements is an important capability for human life, since it provides, as verbal language, the basis for communication [1]. Gait, as a part of the whole body movement repertoire, is also modulated by the emotional state. Here, we investigated the cues underlying the perception of emotions during human walking. While previous studies [2] addressed the question of how emotions can be inferred from whole body gestures using point-light displays, we focus here specifically on the kinematic properties of human gait.

METHODS: <stimuli> To this purpose, we used movie clips of (i) video recorded emotional gaits of professional actors (ii) artificial avatar's gaits created by inverse kinematics from motion capture data of emotional gaits (iii) the same avatar's gait created by manipulating a very few gait parameters in the neutral gait (iv) very short durations (half or a single complete step). In (iii), we manipulated the head and the trunk orientations, as well as the walking speed by scaling the coordinates of the markers in the gait direction and the play speed. **<psychophysics>** Naive subjects had, during or after watching a movie clip on a computer screen, to choose the emotion conveyed by the displayed gait among six possibilities [angry, sad, joyful, fearful, neutral, unknown] using the keyboard.

RESULTS: The results of the psychophysical experiments are shown in Fig.1. It shows that emotions can be correctly recognized significantly in conditions (i) and (ii), and in (iii) except for fear, and in (iv) except for joy.

CONCLUSIONS: Emotions expressed during locomotion can be significantly recognized from the sagittal view (i), even with avatars without textures like facial expressions or hand gestures (ii). This means that the whole body itself conveys emotional information. We found that specific head and trunk postures (their absolute orientations), combined with a particular walking speed, contain enough information (except for fear) to generate an emotional percept (iii), as the recognition rate of artificially generated emotional gaits were comparable to the real recorded ones. Moreover, preliminary results of (iv) suggest that emotions can be well recognized from very short duration (half-step duration) stimuli except for joy. For this particular case, configuration cues (body-posture) seem to be sufficient to generate emotional percepts.

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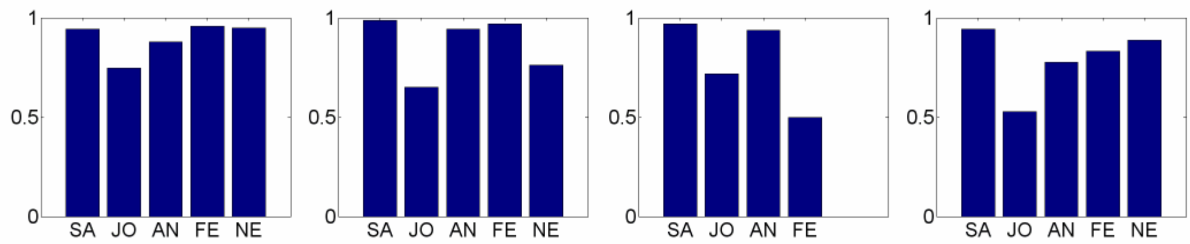

Fig.1 The rate of correct recognition in each experiment for conditions (i),(ii),(iii),(iv), from left to right.

O.26

Cognitive and motor mechanisms underlying ability to divide attention while walking

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INTRODUCTION: The inter-relationship between cognitive ability, motor skills and balance control is complex. It is widely recognized that cognitive impairment is a major risk factor for falls in older adults [1]; however, specific cognitive domains most strongly associated with fall risk and optimal methods to treat these risk factors have yet to be determined. It is critical to disentangle the role of cognitive factors from motor mechanisms in order to develop effective interventions. The goal of this study was to examine the relationship between ability to perform a complex verbal task while walking and underlying balance and cognitive abilities in order to identify the locus of impairment (i.e., cognitive, motor or a combination).

METHODS: Community-dwelling older adults were assessed using the walk while talk complex test (WWT-c), which is a timed task while walking and reciting every other letter of the alphabet [2]. Exclusion criteria included cognitive impairment and inability to walk household distance without assistive device. Participants completed a comprehensive cognitive test battery including assessments of psychomotor speed, perceptual speed, recall memory, working memory, verbal ability, spatial ability, and attention including sustained, selective, and divided attention. Participants also completed a physical performance test battery including hearing, vision, leg strength, gait, and static and dynamic balance. To examine the relationship between WWT-c and cognitive and physical performance measures Pearson Product Moment correlations were calculated (Bonferroni corrected alpha = .005). To identify factors associated with ability to divide attention while walking (i.e., WWT-c) hierarchical regressions were performed ($p < .05$).

RESULTS: Results from 64 older adults (range: 65 – 86; mean age = 75.4 + 5.7 years) reveal strong correlations between gait under dual-task conditions (WWT-c) and underlying cognitive abilities and gait and mobility under single-task conditions. In particular, perceptual speed, divided attention in a cognitive task, sustained and selective attention, gait speed, static balance and a composite measure of mobility were significantly correlated to WWT-c ($p < .005$). Hierarchical regression analysis revealed that two underlying abilities (one motor and one cognitive) explained 52% of the variance of WWT-c. Specifically, gait speed explained 39% of the variance ($p < .001$), while divided attention in a cognitive task independently explained 13% of the variance ($p = .003$).

CONCLUSIONS: The results of this study demonstrate that the ability to walk while performing a complex verbal task relies on both underlying cognitive and motor abilities. Ability to divide attention between cognitive tasks appears to be a critical underlying cognitive resource while gait speed is a critical underlying motor ability of divided attention during gait tasks.

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O.27

Evidence for a relationship between anxiety, visual sampling behaviour and falls risk in older adults performing adaptive locomotor tasks

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INTRODUCTION: There are age-dependent changes to the way vision is sampled during adaptive locomotion. For example, older adults tend to fixate stepping constraints (e.g. obstacles or stepping targets) earlier than, and for longer than, younger adults prior to stepping on or over them [1,2]. Older adults at a ‘high risk’ of falling transfer gaze away from a stepping target earlier than their ‘low-risk’ counterparts or young adults [3]. The extent of premature gaze transfer increases with task complexity and is associated with a decline in stepping accuracy. The aim of the present study was to test the hypothesis that increased anxiety about upcoming obstacles modulates visual sampling behaviour and associated stepping performance.

METHODS: Sixteen older adult (8 high-risk, 8 low-risk) participants walked a 7m walkway placing their right foot into the centre of a target box (if present). The experimental paradigm consisted of 5 conditions (10 trials each): No target or obstacle, 1 target box, 1 target and obstacle separated by 40cm, 1 target and obstacle separated by 120cm, 1 target followed by both obstacles. Movement kinematics, eye movements and electrodermal skin response (EDR) were measured. A 5-point task specific state anxiety questionnaire relating to each condition was also completed by subjects between trials.

RESULTS: Progressively increasing task complexity resulted in associated statistically significant increases in measures of anxiety, extent of early gaze transfer and stepping inaccuracies. These differences were constrained to the high-risk older adults group. We found significant correlations between the level of self-reported anxiety and the extent of early gaze transfer ($r_{(68)} = -.770$, $p < 0.001$) and percentage number of missed steps ($r_{(68)} = .710$, $p < 0.001$).

CONCLUSIONS: Our results provide evidence that increased anxiety about environmental threats to stability experienced by older adults leads to suboptimal visual sampling behaviour which in turn negatively influences stepping performance and contributes to increased falls-risk. This research raises exciting new possibilities for the diagnosis of falls-risk and prevention of falls in older individuals.

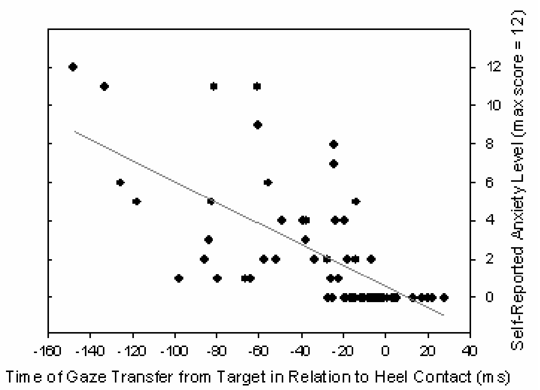

Fig.1 Significant correlation between early gaze transfer and anxiety

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O.28

Effects of instructed prioritization and task difficulty on concurrent walking and cognitive task performance in healthy young adults

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INTRODUCTION: When performing two tasks concurrently (dual task performance), instructions related to task prioritization are presumed to affect task performance. However, many factors may affect the ability to shift task performance in response to instructional set, including task difficulty and individual characteristics (e.g. age, balance abilities, cognition). The objective of this study was to examine the effects of task difficulty on the response to instructed task prioritization during dual task performance in healthy young adults (HYA). We hypothesized that performance of concurrent cognitive and walking tasks would be responsive to instructed prioritization, such that performance of either task would be optimized when participants were instructed to prioritize that task. Further, we anticipated that the degree to which task performance shifted in response to instructed prioritization would be modified by task difficulty.

METHODS: Eleven HYA were evaluated while walking and performing a concurrent cognitive task (auditory choice reaction time task). Performance of walking and the cognitive task were compared under 2 randomized instructional sets – 100% walking focus versus 100% cognitive focus – and during 2 randomized task conditions – usual base of support (UB) walking (n=11) and narrow base of support (NB) walking (n=5). Primary outcome measures included gait velocity for walking and response latency for the cognitive task.

RESULTS: In the UB condition, instructional set had a significant effect on both gait velocity (p=0.003) and cognitive task response latency (p=0.006). Average gait velocity was 1.83 m/s for the 100% walking focus condition and 1.69 m/s for the 100% cognitive focus condition. Average response latency was 0.89 s for the 100% walking focus condition and 0.77 s for the 100% cognitive focus condition. In the NB condition, instructional set did not affect gait velocity (p=0.686) but significantly affected response latency (p=0.043). Average gait velocity was 1.65 m/s for the 100% walking focus condition and 1.64 m/s for 100% cognitive focus condition. Average response latency was 0.81 s for the 100% walking focus condition and 0.71 s for the 100% cognitive focus condition.

CONCLUSIONS: In the UB condition, instructional set significantly affected both walking and cognitive task performance, suggesting that HYA's are able to shift task prioritization and attentional focus in response to instructions under standard walking conditions. In contrast, in the NB condition, instructional set significantly affected only cognitive task performance, suggesting that under more challenging walking conditions, the ability to reduce prioritization of walking may be limited. These findings support our hypothesis that the ability to modify walking speed in response to instructed task prioritization varies with task difficulty, which may reflect the need for increased cortical control during the performance of complex walking tasks. Further research will examine the effects of instructional set and task difficulty on dual task performance in older adults (healthy v. balance impaired) and people with Parkinson's disease. Understanding the factors that affect dual task performance is an important step to providing effective and functional rehabilitation for improved mobility in a variety of populations.

O.29

Chronic stroke patients use a posture first strategy when avoiding obstacles under dual task conditions

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INTRODUCTION: Chronic stroke patients have reduced gait automaticity, increasing the need to cognitively control gait in order not to fall. Previous studies have shown that the addition of a secondary, cognitive task while walking leads to a lower gait velocity, reduced step length and a higher stride-to-stride variability, indicating a dual-task cost on the primary motor task [1]. However, most of these studies did not quantify the dual-task cost on the secondary cognitive task and used unobstructed gait as the primary task. The present study aimed to quantify the dual-task costs on both a complex locomotor task (obstacle avoidance) and a secondary cognitive task in chronic stroke patients.

METHODS: Five stroke patients (> 6 months post stroke, aged 49 ± 16 years) and four healthy controls (aged 48 ±19 years) participated in the study. All patients were able to walk independently without walking aid for more than ten minutes. The obstacle avoidance task was performed on a treadmill at 2 or 3 km/h, depending on the walking ability of the patients. Participants had to react quickly to the release of the obstacle placed in front of the paretic leg (patients) or the left leg (controls). EMG-signals of the biceps femoris (BF) and rectus femoris (RF) were measured bilaterally to determine the reaction times (RTs) of these muscles to obstacle release. The secondary cognitive task was an auditory Stroop task, during which verbal reaction times (VRTs) were measured. Each assessment consisted of a single task (ST) performance of the obstacle avoiding task and a dual task (DT) condition in which obstacle avoidance was combined with the Stroop task. Of each trial, the last VRT before obstacle release was used to calculate the single task performance of the Stroop task. Stimuli were presented continuously. In each condition 18 trials were presented.

RESULTS: In patients, RTs of ipsilateral BF and contralateral RF showed only small increases from ST to DT conditions (BF: 216 ±23 ms vs. 218 ±34 ms; RF: 205 ±24 ms vs. 222 ±45 ms). In healthy participants, RTs of both muscles were lower in comparison with patients, but they were also higher in DT than in ST conditions (BF: 186 ±33 vs. 166 ±20 ms; RF: 204 ±20 vs. 186 ±39 ms, respectively). In the ST condition, VRTs to the Stroop task of patients and controls were 936 ±178 ms and 859 ±7 ms, respectively. However, in the DT condition patients showed a large increase in VRTs of 487 ms (1423 ±76 ms), whereas the VRTs of controls increased by only 174 ms (1033 ±8 ms).

CONCLUSIONS: The addition of a cognitive task during an obstacle avoidance task did not affect the motor task in stroke patients more than it did in healthy controls. However, the cognitive load of the motor task was indeed larger in patients than in controls, as indicated by the much more increased VRTs in the stroke patients. To deal with this challenging task, the stroke participants used a 'posture first strategy', as the dual task costs were largely confined to the secondary task. Other studies have found significant dual task effects on the motor task in stroke patients, but these studies assessed unobstructed gait [e.g. 2,3]. It may be that only in more challenging gait tasks, such as obstacle avoidance, participants really need to prioritize the primary motor task in order to maintain satisfactory performance levels.

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O.30

Task switching during dual task gait training is difficult for people with Parkinson Disease

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INTRODUCTION: Performing an additional task when walking frequently adversely affects gait in people with Parkinson Disease (PD) [1], but recent reports suggests this may be improved with training in some patients [2]. Dual task training studies report that greater improvements occur in older adults when trained in a variable priority manner (switching attention between tasks), than fixed priority (attending equally to both tasks) [3-4]. The aim of this study was to determine the effect of prioritization during dual task walking training on gait under dual task conditions in people with PD.

METHODS: Forty people diagnosed with PD attended a 20 minute dual task walking training session. Half were instructed to attend equally to gait and a variety of added cognitive tasks (50-50%, fixed priority). The other half were instructed to switch attention between tasks with every trial (eg. 80% attention on cognitive task trial 1, 20% trial 2, variable priority). Spatio-temporal gait performance under dual task conditions and correct response rate of the added tasks were measured pre and post training and compared between the two groups. Attendance to each task during training was evaluated via self reported visual analogue scales (VAS), and measurement of gait speed and added task performance during training.

RESULTS: Both groups showed an increase in dual task step length and velocity with training ($p<0.001$). There was no difference in dual task step length ($p>0.511$) or gait speed improvement between the groups ($p>0.686$). Both groups increased their correct response rate of the added task post training ($p<0.007$). When the self-reported VAS scores were investigated, it appeared that the variable priority group did not switch attention between tasks as instructed (mean inaccuracy 36% +/- 18%), whereas the fixed priority group reported maintaining attention closer to their goal (mean inaccuracy 10% +/- 12%). In support, analysis of cognitive task performance during training indicated that it did not alter with varying attention in the variable priority training group as would be expected. That is, it did not improve when participants were instructed to switch attention from 20% to 80% towards that task.

CONCLUSIONS: Whilst varying the priority of attention between tasks is suggested to maximise dual tasking gains with training, this cohort of people with PD found switching of attention between a gait and cognitive task from trial to trial (variable priority training) difficult. This strategy may be more useful as a progression in this population rather than an initial approach. Nevertheless, regardless of prioritization instructions, both groups showed an immediate improvement in dual task ability when walking following specific training.

ACKNOWLEDGEMENTS: This study was supported by an NHMRC project grant ID#511170.

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O.31

Development of spinal postural control: evidence of a four stage process

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INTRODUCTION: Postural control of the trunk creates the basis for all functional movement; however, little is known about how stability of the spine develops. Previous research has typically considered the trunk to be one rigid segment. In normal healthy adults this assumption is reasonable for modelling many postural tasks; however, during development, and more specifically in pathological conditions in which spinal stability is immature or compromised, it may prevent accurate analysis and/or treatment of the condition for postural tasks.

METHODS: The development of spinal control, as reflected by the ability to stabilize the head in space, was examined bimonthly in eight typical infants in a longitudinal study (3 mo -9 mo of age). EMG (12 trunk muscles) and kinematics (magnetic tracking: head, C7 and arms) were collected during 3 minutes of quiet sitting at four levels of external support (under arms, mid-ribs, waist and hips) while the infant was entertained and encouraged to sit quietly with an erect spine.

RESULTS: Across all eight infants and all four levels of support four stages were observed in the development of upright postural control. During stage 1 the infants collapsed and remained suspended at the end of their available range of motion. When they became upset the researcher assisted them back to vertical alignment and released them again. In stage 2 the infants collapsed, attempted to rise but were unable to sustain an upright position. As infants reached stage 3 they were able to remain upright but wobbled continuously from side to side or forward and backward. By stage 4 they were able to refine the amplitude of the wobble and became stable enough to engage in other activities while remaining upright. Fig 1 shows sagittal plane head displacement a) over time (3 minutes) and b) histogram for one infant at each stage of control and one adult (to demonstrate goal of postural control). Fig 2 shows head marker results for a) mean speed, b) RMS and c) mean distance from midline for all eight infants across the 4 stages of control. These data were collected with hip support.

CONCLUSIONS: Knowledge of the process followed by typical infants in gaining control of the spine will lead to greater specificity of evaluation and treatment planning by therapists in treating children with developmental postural deficits.

ACKNOWLEDGEMENTS: Research funded by grants from NIH R01NS38714 and F31NS056726.

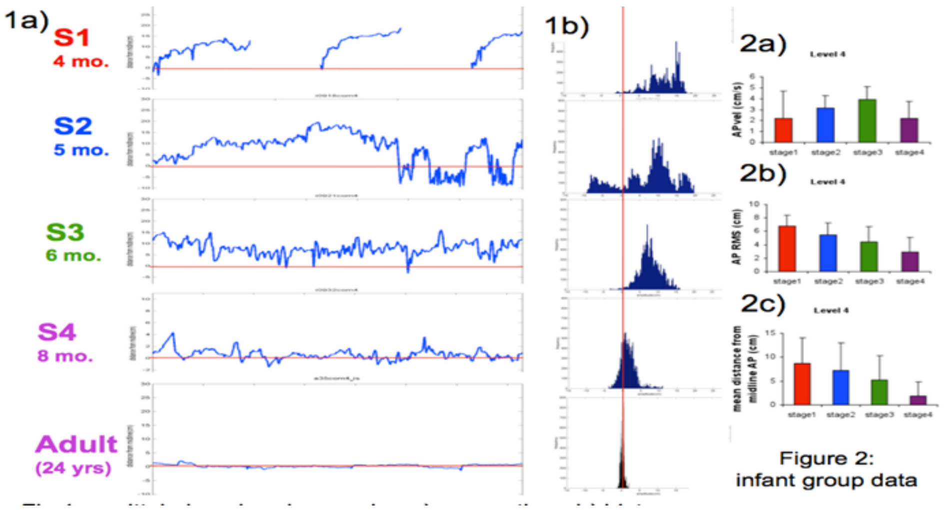

Fig.1 Sagittal plane head excursion a) across time, b) histogram

O.32

Specific characteristics of balancing in children 7-11. Pivotal foot. Motor foot

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Introduction: The purpose of this presentation is to show that as children grow, their balancing maturation processes evolve as well, going through periods of stabilization and disturbances. During this evolution, high values of LFS and VFY are observed, as if the child was using a tactic close to a hip tactic.

Methods: By using Cyber-sabots which allow recording the repartition of CoP of both feet, it is obvious that they are using in fact tactics which are not symmetrical favoring a pivotal foot and a motor foot. (Fig.1). These are the evidence of a motion of the inverted pendulum, where the child's shoulders, essentially on one side, permanently move on a sagittal axis, "a dance of the shoulders" (Fig.2). This motion makes them spin and trace these 2 kinds of pressure recordings.

Results: 197 pupils aged between 8 and 11, were surveyed every 8 months on a 3 year period on this longitudinal stabilometric survey (89 girls and 108 boys). Eyes closed, 72% of children use this strategy at age 9 and only 30% at age 11. Girls evolve faster than boys. (Chi², P=.005)

Conclusion: The maturation process evolves between 9 and 11 years and the difference is significant between girls and boys.

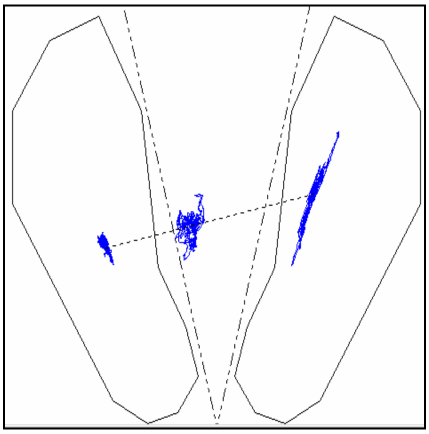

Fig 1 Repartition of the centers of pressure. Left pivotal foot and Right motor foot

Fig 2 The dance of the shoulders

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O.33

The influence of body mass and physical activity on postural stability in children

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INTRODUCTION: Research investigating the effect of adiposity on balance control in children is limited. The purpose of this study is to examine the differences of postural stability among weight groups and the association of physical activity with balance in a sample of young children. Emerging evidence suggests that excess body mass adversely affects postural stability [1]. The sensory systems of overweight individuals may be particularly challenged. Increased fatty deposits on the soles of the feet may impede essential sensory detection. Furthermore, the reduced level of physical activity associated with adiposity may lead to underdeveloped sensory processing [2-4]; and lastly, a young age is associated with an immature postural stability system. All these factors contribute to a very inefficient balance control system observed in children affected by greater body mass.

METHODS: Postural sway parameters were evaluated in 30 children of different body types aged 8-12 years, while they stood as quiet as possible on a force plate for 30 seconds. The experiment consisted of three different sensory conditions: normal standing, standing with eyes closed and head tilted back, and standing on foam. To evaluate the physical activity level children had to complete a self-reported questionnaire.

RESULTS: A statistically significant correlation was found between sway velocity and body mass index (BMI). However, no correlation was observed between postural sway area and BMI. A greater reliance on visual and vestibular information was not observed. In terms of physical activity, a significant correlation with postural stability was observed in the females. The negative correlation between BMI and sway velocity can be associated with a damping effect of inertia. In general, greater body mass did not appear to deteriorate balance control.

CONCLUSIONS: Since age played a significant role for all sway parameters, it is believed that maturation of the neuromuscular system and physical growth have the greatest effect on postural control in children; while the effect of BMI may be obscured.

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O.34

Normal postural performances in dyslexic teenagers during stroop or counting dual tasks

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INTRODUCTION: There is a controversy between clinical and laboratory studies as to the existence of posture deficit in dyslexics. Kapoula and Bucci [1] studied posture stability in quiet stance and reported higher instability in dyslexic than in non-dyslexic children (mean age 13 years); this was the case, however, only when sustained fixation was required. Eye movement recordings indicated instable fixation in dyslexics during this task. When asked to make active vergence eye movements back and forth along the median plane postural control in dyslexics became normal. We suggest that posture instability results from problems with visual attention and the capacity to maintain sustained fixation. The present study follows up this idea and examines older dyslexic teenagers in various dual tasks involving different cognitive process and different use of attention resources.

METHODS: 16 dyslexics (3 females, 13 males, aged from 13 to 17 years), and 12 non-dyslexics (3 females and 9 males, aged from 13 to 16 years) were recruited from a specialized school in Paris. Posture was measured for 26 secs in the following conditions: (a) while fixating a target cross (baseline); (b) while performing a stroop interference test (name color of the word); (c) while performing a stroop flexibility test (name color of the word except when the word is inside a box); (d) while fixating a cross and counting by +1; (d) fixating the cross and counting by +3.

RESULTS: The results show a significant condition effect: relative to baseline the stroop flexibility condition decreased posture stability (increase of surface of COP and of variance of speed). In contrast, counting by 3 increased posture stability (decrease of COP and of antero-posterior sway). Importantly, no group effect or group-condition interaction was found, indicating similar behavior in dyslexics and no-dyslexics. These results show that dual tasks in teenagers could either decrease or increase postural stability depending on the nature of the task. Our observations of posture instability in the stroop test are consistent with the study of young children by Olivier et al. [2]; the improvement of stability with the counting task is consistent with findings in adults [3].

CONCLUSIONS: When involved in a dual task, dyslexics modulate their postural control similarly to non-dyslexics and no difference appears. Posture performance in dyslexics deviates from normal only when sustained fixation control alone is required Taken together prior and present results argue against a real posture deficit in dyslexia.

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O.35

Limb kinematics and walking distance estimation after changing limb segment proportions. Evidence of a locomotor body schema.

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INTRODUCTION: Body dimensions have to be taken into consideration by the central nervous system for planning and execution of the desired movements. During normal development, body schema is constantly updated to continuous changing body dimensions. Here we studied how proprioceptive information and body schema interact, following artificial non-developmental growth of a body segment.

METHODS: We studied locomotion and distance estimation in an achondroplastic child (ACH, 11 yr) before and after surgical elongation of the shank segments of both lower limbs through Ilizarov technique [1], 34 typically developing children and in 6 healthy adults walking on stilts, designed to mimic shank elongation.

RESULTS: Kinematic analysis of gait revealed that dynamic coupling of the thigh, shank and foot changed substantially as a result of elongation. Step length remained unvaried despite the significant increase in total limb length (~1.5 times). These relatively shorter strides resulted from smaller oscillations of the shank segment and significant changes in the inter-segmental coordination (orientation of the thigh-shank-foot covariance plane). Distance estimation was measured by walking with eyes closed towards a memorized target. Before surgery, the behaviour of ACH was comparable to that of typically developing participants. In contrast, following shank elongation, ACH walked significantly shorter distances. Comparable changes in limb kinematics, stride length and estimation of travelled distance were found in adults wearing on stilts, suggesting that path integration [2] errors in both cases were related to alterations in the inter-segmental coordination.

CONCLUSIONS: Strikingly, shank elongation evoked parallel changes in the limb kinematics and travelled distance estimation. Perceptual errors seem at odds with previous studies showing that the body schema in primates may incorporate external objects or tools [3-5] expanding a central representation of the limb endpoint and resulting in a 'functional' elongation of the limb. Our findings indicate that using a tool might differ both functionally and neurophysiologically from changing our own body schema, since our own limb proportions and self-motion representations can be 'conservative', at least as far as it concerns some physiological constraints or predicted sensory consequences of the action. It is also worth noting that usage of proprioception may differ significantly in static and dynamic conditions, since in the dynamic conditions the control system applies some rules [6]. Our results are consistent with a dynamic locomotor body schema used for controlling step length and path estimation. Even at the level of the spinal cord there are some elements of the body schema related to foot motion [7]. We argue that estimation of travel distance may rely on a priori knowledge about intrinsic dynamics of limb segment motion and body proportions.

ACKNOWLEDGEMENTS: The financial support of Italian Health Ministry, Italian University Ministry (PRIN and FIRB projects), and Italian Space Agency (DCMC grant) is gratefully acknowledged.

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O.36

Gender differences in the control of head accelerations during walking in children.

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INTRODUCTION: In young healthy adults, the oscillations of the upper body during level walking are characterised by an attenuation of the linear acceleration going from pelvis to head level [1]. Female adults are able to implement a higher attenuation than male adults, allowing them to reach head accelerations equivalent to those of the males despite higher pelvis accelerations [2]. The aim of this study is to test whether this better control ability of the females is already present in prepubertal age.

METHODS: Two groups of children (Females: n=9, age=9.5 ± 1.0; Males: n=9 age=9.9 ± 1.2) were involved in the study after parental informed consent was obtained. They were asked to walk along a 12 m linear pathway at self selected natural speed and five different trials were recorded. The experiments were conducted in a tested uniform magnetic field. A wearable inertial and magnetic sensor system (MTx, Xsens, fc=100 samples/s) was used to collect movement data at pelvis (P), shoulder (S), and head (H) levels. Three sensors were firmly strapped on the sacrum, in correspondence of C7, and on the head, respectively. The acceleration components were expressed in a laboratory reference frame where the V axis was defined by gravity, the AP axis by the direction of progression (as measured at the beginning of the experiments using an additional sensor), and the ML axis according to a right-handed reference frame. The acceleration time functions for each gait stride were segmented using the AP component of the pelvis acceleration [3]. The RMS of the accelerations of P, S, and H were computed along the AP, ML, and V directions. To quantify the attenuation of the accelerations from pelvis to head level, from shoulder to head level, and from pelvis to shoulder level, the following coefficients [2] were computed: $C_{PH}=(RMS_P-RMS_H)/RMS_P$, $C_{SH}=(RMS_S-RMS_H)/RMS_S$, and $C_{PS}=(RMS_P-RMS_S)/RMS_P$. An unpaired t-test was used to assess the differences between the coefficients computed for the two groups.

RESULTS: As shown by the figure, both groups managed to attenuate the upper body AP accelerations (positive values of the attenuation coefficients), with higher attenuations found for the female group. The difference between the two groups was due to a more effective shoulder to head attenuation in the female group. In the ML direction, negligible values of the C_{SH} were found for the male group, whereas the females managed to attenuate the accelerations also in this direction. No significant differences between the two groups were found in the V direction.

CONCLUSIONS: The results found for the children involved in this study confirmed those reported in the literature for young healthy adults [2], suggesting that gender differences in the ability to control the head accelerations during gait are not merely due to the dictates of cultural prescriptions for gender postures

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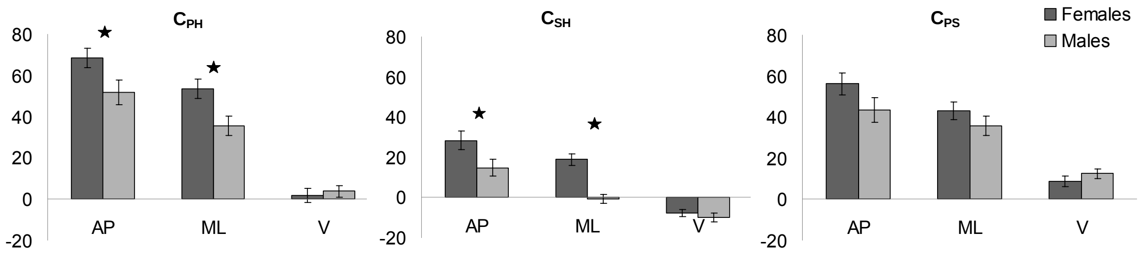

Fig.1 Mean (±s.e.m) values of the coefficients found for the two groups in the three directions. ★=p<0.05

O.37

Treadmill training and gait patterns in infants at moderate risk for neuromotor disabilities

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INTRODUCTION: Complications during the perinatal period may result in either transient neuromotor delay or ultimately a diagnosis of neuromotor disability, such as cerebral palsy (CP)[1]. Infants at risk for neuromotor disabilities often show abnormal muscle tone and motor development delays during the first two years. Treadmill training has been shown to be beneficial in improving gait performance in infants with Down syndrome [2] and children with CP [3,4]. The purpose of this study was to investigate gait performance in infants at moderate risk for neuromotor disabilities (mod-risk) with or without pre-ambulatory treadmill training.

METHODS: Twenty-five moderate risk infants were randomly assigned to either a control (C, n=12) or an experimental (E, n=13) group. Infants entered into the study when they were able to take 10 steps per minute on the treadmill. During the intervention period, infants in the E group received home-based treadmill training for 8 min/day, 5 days/week until the onset of independent walking. Monthly assessments were conducted for all infants at their homes. Once the child could independently walk for 8-10 continuous steps, his/her gait was examined and re-evaluated again 3 and 6 months later (visits 1-3). Children's footprints were recorded via a GaitRite mat to calculate the spatiotemporal gait parameters, including velocity, step length, step width, stance phase and double support phase durations (% of gait cycle).

RESULTS: The results showed that both groups attained independent walking at comparable corrected ages (C: 14.3±2.3; E: 14.4 ±2.4 months). With more walking experience, mod-risk infants increased their step length, velocity, decreased the step, and shortened the stance phase and double support phase durations (all $p<0.05$). A significant group by visit interaction was found for step length, velocity (both $p<0.1$), and stance phase and double support phase parameters (both $p<0.05$). Poorer performance for the C group compared to the E group was observed at visit 1, while the opposite results were found at visit 2. Despite similar intra-subject variability in all infants across both groups, inter-subject variability was reduced for the temporal parameters for the E group at visit 1.

CONCLUSIONS: The treadmill intervention did not modify the onset of independent walking. However, a slight advantage in gait performance was observed in E group at visit 1. We argue that the intervention was terminated too soon resulting in the lack of gait improvements in the E group compared to the C group up to 4 months of walking experience. Overall these results suggest a need to continue the training even after the onset of independent walking for this population. In addition, the treadmill protocol should be modified so more variability is provided to avoid the reduction in temporal inter-subject variability in a population that already has such intrinsic tendency.

ACKNOWLEDGEMENTS: This work was funded by a research grant from the U.S. Office of Special Education & Rehabilitative Services.

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O.38

Quantitative measures of sitting balance relate to measures of standing balance in individuals post-stroke

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INTRODUCTION: Individuals with stroke may be unable to stand independently initially, but with recovery and therapy, may regain the ability to stand. Measures of seated balance in this acute stage could help to quantify the degree of balance impairment resulting from the stroke and to target therapeutic strategies to improve postural control. Indeed, previous studies have found that the ability to sit independently predicts functional outcomes following stroke [1,2]. The purpose of this study is was determine the relationship between sitting and standing balance in individuals with stroke.

METHODS: Participants were recruited from an acute-care hospital, and in- and out-patient rehabilitation centres. An initial sample of 21 subjects (nine women) is reported here (age range: 38-88 years, >1 week post-stroke). Subjects performed four 30-second static tests where they were instructed to remain as still as possible: sitting with eyes open and closed, and standing with eyes open and closed. Two tests of functional stability margins were also conducted in sitting (medio-lateral only; ML) and in standing (ML and antero-posterior; AP). For the static tests, the area, path length and ML and AP root mean square (RMS) of the centre of pressure position were calculated. For the stability margins tests, the total size of the stability margin in each direction was calculated. Each measure from the sitting test was correlated to the corresponding standing measure.

RESULTS: Three subjects had difficulty standing: two could not stand independently, and one was unable to stand with eyes closed. For 2/3 of these subjects, all seated balance measures were more impaired (>3 standard deviations from the mean) than those who were able to stand independently. For the remaining 18 subjects, significant moderate positive correlations between sitting and standing balance tests were observed for all variables with eyes open ($r>0.45$, $p<0.05$), and for all variables ($r>0.63$, $p<0.005$) except AP-RMS ($p=0.28$) with eyes closed. Significant positive correlations were also observed between ML stability margin in sitting and AP ($r=0.67$, $p=0.0047$) and ML ($r=0.6$, $p=0.0013$) stability margins in standing.

CONCLUSIONS: We have demonstrated an association between current measures of sitting and standing balance. Therefore, it may be feasible to use quantitative measures of seated balance in the acute stage to predict recovery of standing balance after stroke. Longitudinal studies comparing seated balance measures in the acute stage with recovery of standing balance are required to test this hypothesis. Such measures could be used in the early identification of individuals requiring intensive balance rehabilitation and to aid in post-acute care decision making.

ACKNOWLEDGEMENTS: Supported by the Heart and Stroke Foundation Centre for Stroke Recovery, Heart and Stroke Foundation of Canada, Canadian Institutes of Health Research, Canadian Stroke Network.

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O.39

Abnormal coactivation of knee and ankle extensors is related to transmission changes in spinal pathways and clinical scores of motor function in chronic hemiparesis after stroke

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INTRODUCTION: A pathological extension synergy is often observed in the paretic leg of stroke individuals during voluntary efforts [1]. As a part of this synergy, an abnormal coactivation of ankle extensors during maximal voluntary extension of the knee has been measured in hemiparesis following stroke [2]. Specific overactivity of knee and ankle extensors was found to be a component of gait disorders [3]. The mechanisms underlying this pathological synergy are still unclear. Recently, we found changes in heteronymous spinal pathways linking quadriceps to soleus that are related to motor deficits in the paretic leg [4]. This study was performed to assess: 1) the coactivation of knee and ankle extensors at the paretic leg in static conditions and 2) whether this coactivation is related to a) the impairment of the intersegmental pathways linking quadriceps to soleus and b) clinical scores of motor function.

METHODS: Ten healthy control and thirteen stroke individuals participated in the study. The coactivation of knee and ankle extensors was assessed during two tasks: a maximal isometric voluntary contraction (MIVC) in knee extension and a MIVC in plantarflexion. The intersegmental pathways linking Quads to Sol were explored by measuring the effects of the stimulation of femoral nerve (FN) (at 1.2 x MT of VL) on soleus voluntary EMG activity. Coordination (LEMOCOT), motor impairment (CMSA), Spasticity (CSI) levels and comfortable gait speed were also measured.

RESULTS: In the two tasks tested, levels of coactivation of knee and ankle extensors were significantly increased at the paretic leg compared to that observed in the control group (Fig. 1). In the stroke group, the early heteronymous facilitation of Sol voluntary EMG activity after FN stimulation was increased and the later inhibition was decreased (Fig. 2). The abnormal coactivations of ankle extensors during the knee extension task were correlated with the increased facilitation and reduced inhibition in the spinal pathways. Moreover, coactivation of gastrocnemius and quadriceps was related to coordination, motor impairment, spasticity and comfortable gait speed levels (Table 1)

CONCLUSIONS: The hyperfacilitation and the lack of inhibition of the plantarflexors voluntary EMG, revealed by stimulating quadriceps proprioceptive afferents, could participate in the abnormal coactivation of knee and ankle extensors at the paretic leg. Strong correlations between coactivation of the gastrocnemius (a biarticular muscle) and clinical scores suggest a functional impact of these deficits.

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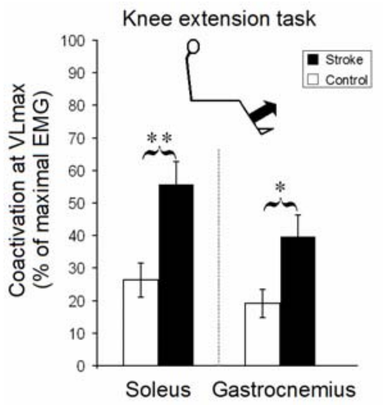

Fig.1 Coactivations between knee and ankle extensors

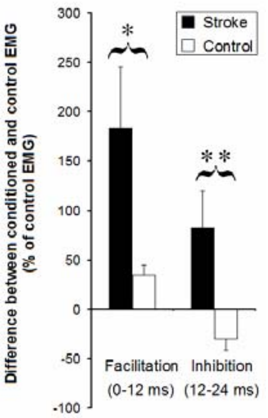

Fig. 2 Modulation of soleus EMG after FN stimulation

	LEVELS OF COACTIVATION AT VLmax	
	SOLEUS	GASTROCNEMIUS
MODULATIONS		
FACILITATION (0-12)	**0.59***	**0.59***
INHIBITION (12-24)	**0.56***	**0.55***
CLINICAL SCORES		
LEMOCOT	-0.15	**-0.76****
$CMSA_F$	-0.33	**-0.75****
CSI	0.42	**0.75****
GAIT SPEED	-0.47	**-0.64***
Spearman *rho* *p≤ 0.05;** p≤ 0.01		

Table 1 Correlations between levels of coactivation, spinal modulations and clinical scores

O.40

An exploratory analysis of spatial and temporal characteristics of intersegmental head and shoulder rotation in people early after stroke

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INTRODUCTION: Studies in healthy individuals have described a clear sequence of head and shoulder coordination during horizontal gaze transfers; the head rotates before the shoulders. In people after stroke, evidence suggests that sensorimotor integration of postural adjustments and voluntarily head movements may have been modified. The aim of our study was to examine spatial and temporal characteristics of intersegmental head and shoulder coordination when looking at a target 90° from centre in people early after stroke.

METHODS: We recruited people after stroke from Southampton General Hospital and healthy controls. Participants were in a seated position and asked verbally to look to their side of preference at a visual marker placed at 90° from centre. LED markers were attached at standardised positions on the body and 3-D motion recordings were made using CODAmotion. Variables collected were total head and shoulder rotation, delay of shoulder rotation, and head and shoulder velocity. Data analysis consisted of non-parametric descriptive statistics and non-parametric inferential statistics (Mann-Whitney U tests) to compare variables between people after stroke and healthy controls. Level of significance was set at $p<0.05$.

RESULTS: Our sample included 18 people after stroke (14 males, median (IQR) age 69 (20) years, median time since stroke 3 (3) weeks) and 17 healthy controls (6 males, median age 66 (11) years). People after stroke were clinically assessed with the Rivermead Motor Assessment (median total score 30 (18) out of 38) and Berg Balance Scale (median total score 52 (16) out of 56). The results of our study are presented in Table 1 and show relatively lower values for all variables for people early after stroke in comparison with healthy controls. A significant between-group difference was found for the delay of shoulder rotation ($p=0.049$), with people after stroke showing less dissociation between head and trunk rotation in comparison with healthy controls. A post-hoc analysis was carried out on the shoulder rotation in our study as we noticed that a number of participants showed contralateral counter rotation of the shoulders before shoulder rotation to the side of head rotation. Our analysis revealed that significantly more people after stroke (9 out of 18) counter rotated with the shoulders in comparison with healthy controls (2 out of 17, $p=0.027$). Shoulder counter rotation for people after stroke ranged from 0.01 to 0.67 degrees and for healthy controls from 0.03 to 0.25 degrees.

CONCLUSIONS: Our results suggest that intersegmental head and shoulder rotation is modified early after stroke. The significantly smaller delay of shoulder rotation could indicate an impaired dissociation between head and shoulder coordination in people early after stroke. Further investigation should confirm this and could relate this finding to problems in mobility, balance and falls as head and shoulder rotation are common in several activities of daily living. The shoulder counter rotation revealed in our study should be interpreted with caution as signal noise could be a confounding factor.

ACKNOWLEDGEMENTS: This study forms part of a larger programme of research funded by the UK Stroke Association.

	Head rotation (degrees) Med (IQR)	Shoulder rotation (degrees) Med (IQR)	Shoulder delay (seconds) Med (IQR)	Head velocity (deg/sec) Med (IQR)	Shoulder velocity (deg/sec) Med (IQR)
People after stroke	54.6 (12.9)	2.7 (5.2)	0.2 (0.1)	49.9 (42.1)	1.8 (6.5)
Healthy controls	56.3 (13.7)	3.9 (5.2)	0.3 (0.2)	64.1 (35.5)	4.6 (6.8)
p-value	0.08	0.717	0.049	0.176	0.248

Table 1 Spatial and temporal characteristics examined in our study

O.41

Postural behaviors to combined visual and base of support pitch disturbance in healthy adults and patients post-stroke.

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INTRODUCTION: Diminished or delayed somatosensory feedback in the elderly and in patients who are post-stroke may cause greater reliance on visual inputs to maintain balance. We have investigated the degree of visual dependence of healthy young and elderly adults and patients who are post-stroke, and explored whether their postural reactions reflect this relative visual dependence when presented with a disorienting visual field and coincident base of support disturbance.

METHODS: Three healthy elderly, 3 healthy young adults, and 3 patients with stroke gave informed consent. All subjects completed a Rod and Frame test of visual dependence. Subjects stood on a dynamic platform within a 3-wall virtual reality environment. After 5 sec of quiet stance, the platform was rotated in 3°of dorsiflexion at a constant velocity 30°/sec. The visual field simultaneously rotated in upward pitch at velocities of 30, 45 or 60°/sec. The platform maintained a 3° tilt for 30 sec, and then slowly returned to the horizontal at a constant velocity of 0.1°/sec over a 30 sec period as the visual field continued rotating. Total trial duration was 65 sec. An additional trial was performed in the dark. Reflective markers on body segments (Motion Analysis, CA) were used to calculate center of mass (COM) in the sagittal plane. One regression line was fit to the COM between the interval of tilt (5-35 sec) and another line was fit to the COM during the interval when the platform returned to neutral (35-65 sec). Slopes of the regression lines were compared between the groups using paired *t*-tests.

RESULTS: Errors in the estimation of vertical during the Rod and Frame test were 1.8°±0.9 for the young adults, 5.6°±5.8 for the elderly, and 15.2°±7.4 for the patients. Patients had significantly larger errors ($p<0.002$) than healthy young and elderly adults, suggesting greater visual dependence. During combined visual field and platform motion, COM of the young adults was initially displaced anteriorly to compensate for the backward tilt and then overshot their initial position as it moved posteriorly to a steady state. Elderly subjects exhibited a brief anterior compensation and then overshot their initial position as the COM moved posteriorly. Patients with stroke demonstrated a stronger response exhibiting large backwards COM displacements requiring additional support which did not occur when the platform was tilted without visual scene motion. These differences emerged in tilt period of the trial with significantly smaller negative or positive slopes in the elderly subjects than in young adults ($p<0.01$) and in the stroke vs. the young ($p<0.002$) across all velocities of visual motion (Fig 1A). For both periods, it is clear from the figure that slopes increased incrementally with scene velocities up to 45°/sec for all populations. As the platform returned to neutral (Fig 1B), both young adults and patients exhibited faster COM velocities than the elderly. Young adults had significantly greater slopes than elderly ($p<0.005$), and patients had significantly greater slopes than both the young and elderly ($p<0.005$). All subjects again overshot vertical, moving their COM far anterior of their initial position in space.

CONCLUSIONS: All populations were affected by the visual scene velocity, but elderly subjects demonstrated smaller amplitudes and more frequent oscillations of the COM to the initial base of support tilt suggesting more rigidity. Greater slopes in the patients suggested they were more sensitive to visual motion than the other populations.

ACKNOWLEDGEMENTS: Supported by NIH-NIA grant AG26470.

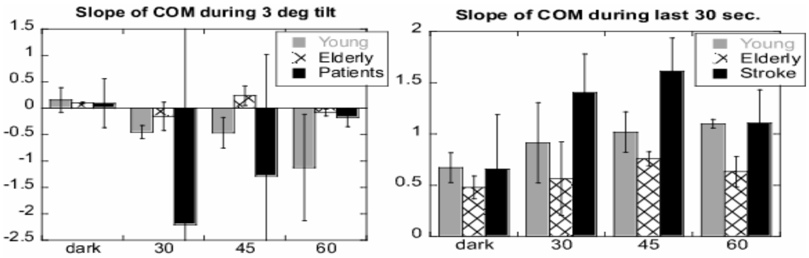

Figure 1 A: Slope of the line fitted to COM over the 30 sec. when the platform was tilted. B: Slope of the line fitted to the COM over the 30 sec when the platform returned to neutral for each visual field velocity.

O.42

The effect of additional hand contact on postural stability perturbed by moving environment in patients after stroke

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INTRODUCTION: Individuals with hemiparesis following stroke have difficulties maintaining postural stability in environments with conflicting visual and somatosensory inputs. Additional external hand contact or holding an object in the hand have been shown to increase postural stability perturbed by moving environment in young healthy individuals. Having this in mind we proposed that similar mechanisms of additional somatosensory stimulation may help stabilize posture in moving environments for vulnerable individuals with post-stroke hemiparesis. To test this hypothesis, we analyzed the stability of upright posture in individuals with hemiparesis holding a small weight in their hand while receiving conflicting visual stimulation.

METHODS: Nine individuals with hemiparesis (58±10 years) following a stroke in the area of the left (#4) and right (#5) middle cerebral artery participated in the study. They had severe to mild motor deficit ranged from 22 to 64 out of 66 possible Fugl-Meyer Arm motor section scores. Balance Scale scores ranged from 38 to 53 out of 56 possible. While standing for 45 sec, in front of a screen, participants with hemiparesis observed a projection of a boat that rocked up and down on water in the sagittal plane. In randomly assigned trials they were standing on the floor with or without visual stimulation in three conditions: with arms at sides, with weight in unaffected hand, and weight in affected hand. Subjects were then asked to repeat these trials while standing on foam to further decrease somatosensory information from the feet. Kinematic data were collected from the markers placed on the sacrum, anterior superior iliac spines, toes and at the joints of the hip, knee, and ankle. Amplitude and velocity of the center of mass displacement, and angular displacement of the thighs and shanks in the sagittal and frontal plane were analyzed and compared between different experimental conditions.

RESULTS: Compared to the trials with no weight, holding a weight in the unaffected hand decreased the amplitude and velocity of the center of mass displacement in all conditions, including standing on the floor and foam. Holding the weight in the affected hand decreased the postural sway to a lesser extent.

CONCLUSIONS: Results showed that unilateral stroke disrupts the mechanisms of postural stabilization. Specifically, the affected hand of individuals with hemiparesis is less able to provide appropriate somatosensory inputs which can be integrated into postural responses to moving environment. This may partially be due to an abnormal pattern of muscle activation or functional non-use of the paretic hand. However, somatosensory information from a light weight held in the unaffected hand appears to increase stability, similarly to healthy subjects. These results may help patients post stroke increase stability and decrease risk for falls by giving them a tool to improve integration of incoming sensory information.

O.43

Visually-triggered step adjustments are substantially impaired in mildly affected stroke subjects

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INTRODUCTION: Successful walking in a cluttered environment makes demands on a number of sensori-motor processes that could be disrupted by a stroke. This may impair the ability to avoid obstacles with the feet when walking and lead to falls. Indeed, previous studies have shown impaired obstacle avoidance abilities in stroke subjects [1-3]. Here we attempt to identify which of the processes are most at risk by studying visually-triggered on-line step adjustments. We hypothesised that step adjustments in stroke subjects could fail either because the change in foot trajectory is inadequate or because the ability to maintain balance during an adjustment is impaired.

METHODS: A total of 10 stroke subjects (age 32 – 63 y, mean 50 y) participated who had recovered from a stroke leaving only mild lower-limb impairment (Fugl-Meyer scores 86-100%; Motricity Index 69-100%). Ten healthy subjects in the same age range were included as a control group. Subjects stepped onto an illuminated rectangle which could jump 140mm either medially (p=0.2) or laterally (p=0.2) at the instant the stepping foot left the ground, thus provoking a mid-step adjustment. In a separate block subjects performed the same task but with the body supported by a frame to eliminate the need for balance responses. We determined the kinematic onset latency of the step adjustment, the foot placement error relative to the jumped target, and the speed at which the step was adjusted in the medial/lateral direction.

RESULTS: Stroke subjects were able to produce foot trajectory adjustments at short latency. The latency, however, was slightly longer for the affected (148ms) than the unaffected leg (141ms; p = 0.049) and the latencies of the stroke subjects were longer than for the control subjects (129ms; p = 0.034). Overall, stroke subjects had more difficulties than controls landing on the jumped target, but particularly in unsupported medial jumps the foot fell further from the target (stroke 104mm; control 33mm; p = 0.023). In both jump direction and support conditions, the ability of the stroke subjects to land on the jumped target was not different between the affected and unaffected leg. The average speed at which stroke subjects adjusted their steps in medial jumps was substantially reduced compared to controls, with much larger reductions in unsupported than supported conditions (stroke 0.13m/s and 0.28m/s; control 0.42m/s and 0.40m/s, respectively; p = 0.033). Lateral adjustment speeds were not different between groups.

CONCLUSIONS: The results show that these mildly impaired stroke subjects had deficits in initiating and executing visually-triggered adjustments of foot trajectory. Execution of step adjustment was particularly impaired when the target jumped medially, but to a much larger extent when the body was unsupported than when it was supported. This finding indicates that the stroke subjects had profound difficulties with balance control during the step. This caused them to suppress mid-step adjustments of foot placement particularly in the medial direction, which was the greater threat to balance. Paradoxically such suppression in the real world may also threaten balance if it leads to obstacle collision.

ACKNOWLEDGEMENTS: This study was supported by the Medical Research Council and a grant from the Dutch Brain Foundation ('Hersenstichting') to JHN.

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O.44

Change in gait variables during modulation of speed in patients post-stroke and healthy subjects

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INTRODUCTION: It is well known that most patients post-stroke walk slowly and with asymmetry. However, it is not known to what degree these patients can modulate walking speed and to what degree such modulation affects basic gait variables and asymmetry. We therefore wanted to investigate change in cadence, step length, and asymmetry when patients post-stroke where instructed to walk at different speeds.

METHODS: 27 patients post-stroke with hemi-paretic gait and 28 healthy persons were included. Gait was measured for 7 meters steady state walking at preferred speed, slowly, and fast but safely. Time was measured by a wireless photo cell timing system. Trunk acceleration was measured along anteroposterior (AP), mediolateral (ML) and vertical (V) axes using a wireless kinematic sensor attached to the lower trunk. Cadence, step length, and interstep trunk acceleration asymmetry were estimated from acceleration signals and used as outcome measures. Gait asymmetry was calculated as the difference between autocorrelation coefficients representing step and stride regularity. From data obtained at preferred and fast speed, slope (change in a variable per unit change in velocity) was calculated for each subject. To demonstrate how individual slopes differed between subjects and groups, individual slopes for cadence, step length and AP asymmetry were plotted against individual preferred gait velocity (Fig. 1) and regression lines constructed for each of the two groups.

RESULTS: Mean velocity for patients post-stroke was 0.67 m/s (range 0.17-1.08) and for healthy persons 1.44 m/s (range 1.14-1.76). Slow walkers among patients demonstrated steeper individual slopes for cadence compared to fast walkers among patients, while healthy subjects had similar individual slopes irrespective of their walking velocity. This indicates that patients who demonstrated low preferred velocity changed their cadence more per unit velocity than fast walkers in the same group when instructed to walk at preferred and fast speed. For healthy persons the change in cadence per unit change in velocity was independent of preferred walking velocity. For step length however, the individual slopes for patients and healthy persons were more similar, suggesting change in step length per unit change in velocity was independent of both group and preferred gait velocity. Individual slopes of AP asymmetry were close to zero for both groups, indicating that degree of asymmetry was not affected by modulation of gait speed. Similar results were obtained for V and ML asymmetry.

CONCLUSIONS: Change in individual gait variables per unit change in velocity when measured at preferred and fast velocity in patient post-stroke showed different patterns for different variables. This may affect clinical reasoning for choice of walking speed in patients post-stroke during overground and treadmill walking.

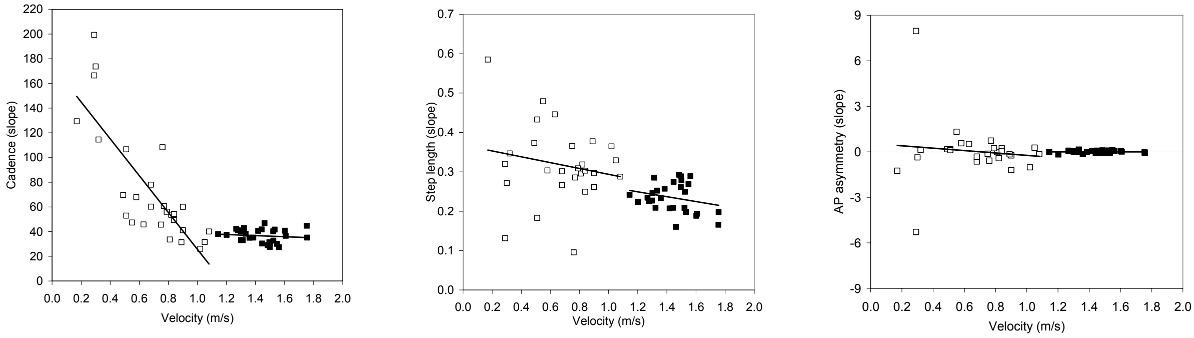

Fig.1 Markers indicate individual slopes (change in a variable per unit change in gait velocity) for cadence, step length and anteroposterior (AP) asymmetry. Patients post-stroke (□) and healthy persons (■)

O.45

Kinematics of turning during the Timed Up and Go in chronic stroke survivors with and without a falls history

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INTRODUCTION: Almost half of stroke survivors living at home more than six months after stroke will fall, and around half of these falls will occur while they are turning [1]. The purpose of this study is to quantify kinematic differences between a sample of community-dwelling chronic stroke survivors and age-matched healthy counterparts in turning coordination during the 180 degree turn around in the “Timed Up and Go” test (TUG) [2] and to quantify any differences in turning coordination between participants with stroke who have a history of falls (SF) and those with no falls history (SNF).

METHODS: Eighteen participants with stroke (9 SF and 9 SNF) and age-match controls (9CF, 9CNF) were asked to perform 20 TUG walks in which direction of each turn-around (10 left and right) was cued prior to the start of the trial. Participants were asked to stand up (from a starting position in the chair with knees at 90degrees), walk three metres (to a mark on the floor), turn around, walk back and sit down. Full body kinematics (Plug-in-gait (PiG) marker set-up) were measured with 13 Vicon (Oxford Metrics) cameras at a sampling frequency of 120 Hz. Repeated measures ANOVA with: between-subject factor group (SF, SNF, CF, CNF) and within-subject factor of turn direction (paretic or non-paretic turns) was used for analyses.

RESULTS: Stroke patients were >6mths post-stroke and had residual paresis (scored <34 on the Fugl-Meyer Lower Limb subscale). Stroke patients had significantly longer TUG times than age-match counterparts (P<.000). However, there were no differences between stroke patients or age-match control subgroups with and without a falls history or according to direction of turn (see Figure 1). Time to turn was not significantly different between groups or direction of turn with the mean time to turn (SD) 2.36 s (±.97), 1.68 s (±.56), 2.60 s (±1.44 and 2.54 s (±1.99) for CF, CNF, SF and SNF groups respectively. Axial segment onset latencies were not different between groups or direction of turn. No significant differences of onset latencies between segments, indicates all participants use an *enbloc* strategy of axial segment reorientation to carry out the turn (see figure 2).

CONCLUSIONS: This sample of community-dwelling chronic stroke survivors were able to perform a 180 degree turn during the TUG in a similar way to healthy age-matched counterparts regardless of falls history and residual paresis in the lower extremities. Although TUG times were different between participants with stroke and age-match counterparts they were not different between groups of stroke patients with and without a falls history. There were no differences between groups in time to turn, number of steps taken or in the temporal coordination of axial segment reorientation, indicating recovery of movement patterns alone is insufficient to prevent falls.

ACKNOWLEDGEMENTS: This study was funded by the Stroke Association

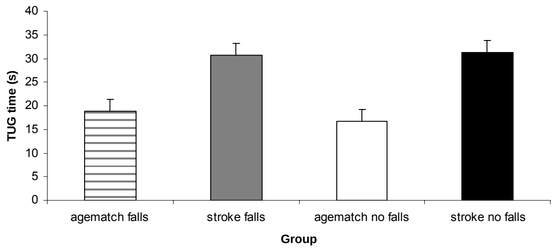

Fig. 1 Mean TUG times according to group

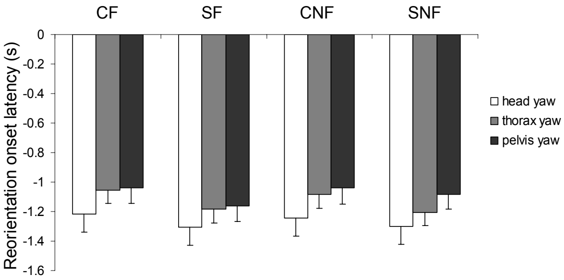

Fig. 2 Mean axial segment reorientation onset latencies according to group

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O.46

Factors affecting body balance control during interpersonal light touch

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INTRODUCTION: If an upright standing individual keeps light finger tip contact with an external reference, the tactile sensory feedback received is used to enhance the accuracy of postural adjustments and the variability of postural sway is reduced. This effect is not restricted to situations were a single individual holds contact with an inanimate but generalized to light touch contact between two individuals. In a previous study [1], we have shown that postural sway is reduced in the elderly when keeping light contact with another person's hand. In the present studies, we investigated this effect of 'interpersonal light touch' (IPL) further in order to determine whether it is affected by the qualities of the light touch and the postural symmetry between both individuals.

METHODS: Six pairs of healthy adult participants were tested in quiet upright standing, almost shoulder to shoulder, facing forwards on separate force platforms. The participant on the left always extended the right arm forward while the other extended the left. In order to investigate the effects of asymmetrical joint postures, each participant was standing in normal or tandem Romberg stance and both participants kept the same or different stance postures, thus resulting in four different joint posture combinations. Each participant's body sway was recorded with eyes closed under three touch conditions: contact with the index finger of the adjacent hand of the other participant ('Finger light touch'), contact near the shoulder of the other participant ('Shoulder light touch') and without any contact ('No contact'). Four standing trials of 30 seconds duration were recorded for each of the 12 possible joint postures. Within-trial sway variability was calculated as the standard deviation of the CoP rate of change (SD-dCoP) and averaged across trials for each condition. Mixed repeated-measures ANOVA with touch, joint postural difference (same/different) and sway direction as within-subject factors were computed for SD-dCOP.

RESULTS: Reliable reductions of body sway variability were found under both interpersonal light touch conditions compared to the No contact control. We also found, however, interactions between each individual's standing posture, the touch conditions and the joint postural difference. When in normal stance, interpersonal light touch reduced the variability of sway except when in shoulder contact with a partner currently in tandem stance, which increased variability. On the other hand when in tandem stance, body sway is always reduced with interpersonal light touch (Shoulder light touch>Finger light touch) with an extra reduction of sway if the partner is in normal stance.

CONCLUSIONS: We have shown that interpersonal light touch at the finger tip, like light touch to an inanimate external reference, or near the shoulder shows a very reliable beneficial effect on the variability of body sway during upright tandem or normal standing. In addition, one also benefits from the intrinsic stability of the partner if he/she keeps a qualitatively more stable stance. In contrast, keeping close light physical contact near the shoulder with a partner who is qualitatively much more unstable results in increased variability. This, however, is not the case if interpersonal light touch is limited to just finger tip contact which also improves sway even when the partner is in tandem stance. We can conclude that the shear forces at the finger tip skin are possibly used to augment the signal from the proprioceptive and vestibular senses to improve the accuracy of postural adjustments during upright standing even when contact is made with another individual who himself shows variability of body sway.

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O.47

Trunk activity in human, from posture to locomotion

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INTRODUCTION: Since the first studies on human locomotion, motor control investigations have mainly examined lower limbs as the prime actors in locomotion, while the trunk and its control during walking have received less attention. In humans, the trunk represents 60 % of total body mass with a high position above the feet that gives it an important leverage effect on the "inverted pendulum". However, the trunk is highly articulated and actuated by many muscles, providing it the versatility to participate actively in the various tasks that humans undertake, while maintaining trunk balance. This versatility suggests a complex regulation of trunk movements resulting from a combination of anticipatory and reactive muscular actions.

METHODS: To understand the principles underlying this synergy we investigate trunk movements during gait initiation and walking with a precise analysis of trunk kinematics and corresponding axial muscle EMGs synchronized with dynamic analysis of gait. To this end we recorded shoulder, spine and pelvis kinematics and the bilateral activity of the *Erector spinae (ES)* at five spinal levels. We also recorded *tibialis anterior* and *gastrocnemius* muscles activities together with dynamic parameters from force plates and limb movements.

RESULTS: The ES muscle presented a metachronal descending activity both during walking and during gait initiation before the first step, extending results from a precedent study (1). Trunk kinematic data showed how the trunk leans in the sagittal plane during gait initiation by modifying lordosis curvature. In the frontal and horizontal planes, trunk presented one lateroflexion and one rotation on each side per stride. In those planes, trunk activity seem to occur before in the upper trunk and after in the lower trunk since the initiation phase, as result of trunk muscles activity and limb movements.

CONCLUSIONS: Our data allowed us to gain further insight into 1) the role of ES activity in normal walking, how they facilitate rising the pelvis and the leg and contribute to drive trunk movement, 2) when begin the walking program commanding trunk activity, how is handled the transition between postural state and locomotion.

ACKNOWLEDGEMENTS: This work was funded in part by the Ministère de la Recherche (ACI Neuroscience; ACI Plateformes Technologiques 032645), by the Région Aquitaine, and by the DGA (Délégation Générale pour l'Armement, N°0334045). This work is a cooperation between the CNRS UMR 5227 and the Demar team in the INRIA.

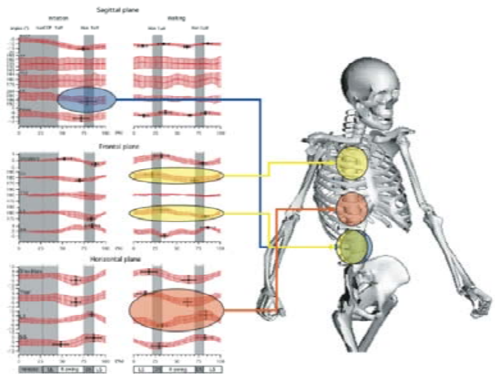

Fig.1 Kinematics data during gait initiation and walking

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O.48

On the relationship between body orientation and direction of motion during human locomotion

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INTRODUCTION: Our work aims at understanding the shape of trajectories that humans choose to walk in free space, in particular to close-by targets. In many cases, the direction of motion of humans is coupled to the (forward) orientation of the body [1 – 3]. This concept is known from wheeled robots as "nonholonomic motion" (Fig. 1). However, in contrast to wheeled robots, humans are capable to perform sideward or diagonal steps ("holonomic" forms of motion, i.e. direction of motion and body orientation are decoupled), and in certain situations they may very well do so. But when (where) does this holonomic behavior occur? Understanding this characteristic of humans is important for establishing good models of locomotion.

METHODS: We have developed an analytical tool that can decompose any given trajectory data into holonomic and nonholonomic parts. This tool is applied to new experimental data of 10 subjects performing 200 trajectories to close-by targets each. Positions and orientation of the subjects are deducted from shoulder markers. We investigate the dependency of appearance of holonomic behavior on locomotion speed and distance to origin and target points.

RESULTS: The analysis of free motion trajectories confirms that indeed there is a strong relationship between body orientation and direction for human locomotion. Only very short trajectories are holonomic (e.g. to a target 0.5 m to the right or left), but for longer motions, a nonholonomic phase appears in the middle part while the beginning and end phase are marked by holonomic behavior, i.e. there is a dependency of the behavior on the distance from origin and goal. The analysis also shows that there is a correlation of nonholonomic behavior and low speeds. Based on this, realistic models of locomotion trajectories can be established.

CONCLUSIONS: Most of the locomotion modeling studies considers only the evolution of the body position. Our contribution is to show that fully understanding the interactions between body orientation and direction of motion in human locomotion is crucial for obtaining good models. This work can be extended by including obstacle avoidance and potential preferences of human locomotion in form of optimization criteria.

ACKNOWLEDGEMENTS: This work is financed by French ANR project "Locanthrope".

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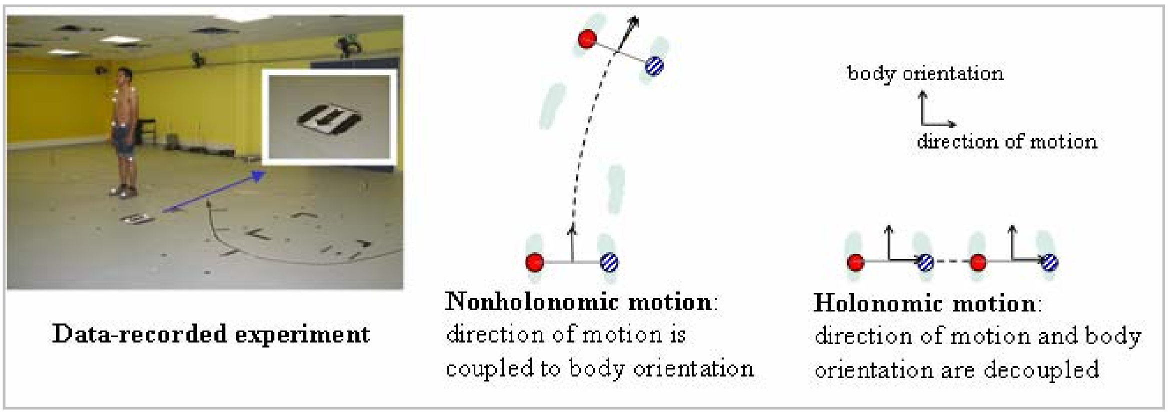

Fig.1 The relationship between direction of motion and body orientation

O.49

How vision influences postural stability during locomotion

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INTRODUCTION: Visual has been shown to influence locomotion for wayfinding, obstacle avoidance and stability. In the latter case of stability, the measures used to characterize stability have primarily been based in the time domain, such as cross-correlation. Far fewer studies have used frequency domain measures. Here we show that frequency analysis fosters an understanding of how vision stabilizes locomotion primarily by stabilizing postural control.

METHODS: Subjects walked or stood on a treadmill in five conditions (posture, stepping-in-place, 1 km/hr, 3 Km/hr, and 5 km/hr) in front of a 2.5 m by 1.8 m virtual display. The visual scene consisted of 500 triangles translated in the A/P direction at 10 frequencies simultaneously (sum-of-sines) for 2 minutes. Frequency response functions (FRFs) were computed as the A/P displacement of 21 bilateral kinematic markers. Gain and phase were computed at each of the 10 stimulus frequencies. Muscle activity from 12 muscles was also recorded.

RESULTS: Coupling to the visual display was observed in all conditions, indicated by consistent gain and phase responses, but gains between all body segments and the visual display were highest in the stepping-in-place and locomotion conditions. Particularly at the low frequencies of body motion, where all body segments were in phase, gains were higher by a factor of 10 during stepping-in-place and locomotion than during posture. Gain between vision and body segments at gait cycle frequencies had inconsistent phases, indicating weak or no coupling to the frequencies of the gait cycle. All subjects reported perceiving movement of the visual display during the posture condition. During stepping and locomotion, perception of the visual display "froze" to become a solid wall of triangles.

CONCLUSIONS: Our results suggest that sensory feedback for stability is crucial for locomotion, but may play the most important role at non-locomotion frequencies. Higher gains were observed for both stepping-in-place and locomotion, suggesting that the basis for increased coupling to vision is not locomotion per se, but freeing the constraint of maintaining the feet fixed in place. Freeing the feet results in a direction of neural stability which may foster stronger coupling to aid stability of locomotion.

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O.50

Eyes or head: which has the greatest effect on steering control?

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INTRODUCTION: Previous works has shown that head rotations cause path deviations whether the individual actively turned his or her head or it was perturbed externally [1,2]. Research looking at eye movements has shown that saccades precede a change in direction [3]. We wanted to test whether path deviations during goal-directed walking depended on a head turn alone, a gaze shift alone, or both together.

METHODS: Participants (N=11) walked along a 7m path towards a central goal. Eye movements were recorded with an ASL MobileEye tracker, and head and body kinematics with an Optotrak Certus system. The following conditions were used: (a) active head turn towards a target light, with free eyes (ATL); (b) active head turn in response to a verbal command, with free eyes (ATV); (c) active head turn in response to a verbal command, while maintaining fixation on the locomotor goal (HNE); (d) saccade in response to a verbal command, while keeping the head facing the locomotor goal (ENH); and (e) active head turn and gaze shift in response to a verbal command (ENH).

RESULTS: Trunk COM deviations (unsigned) in the medial/lateral direction showed that the largest path deviation was produced by an active head turn in the direction of a target light, with gaze free (~3cm). The other conditions were not significantly different from each other (~2cm).

CONCLUSIONS: The results suggest that both eyes and head contribute to slight path deviations, however head turns in response to an exogenous cue generate larger deviations. Therefore path deviations result from changes in attention.

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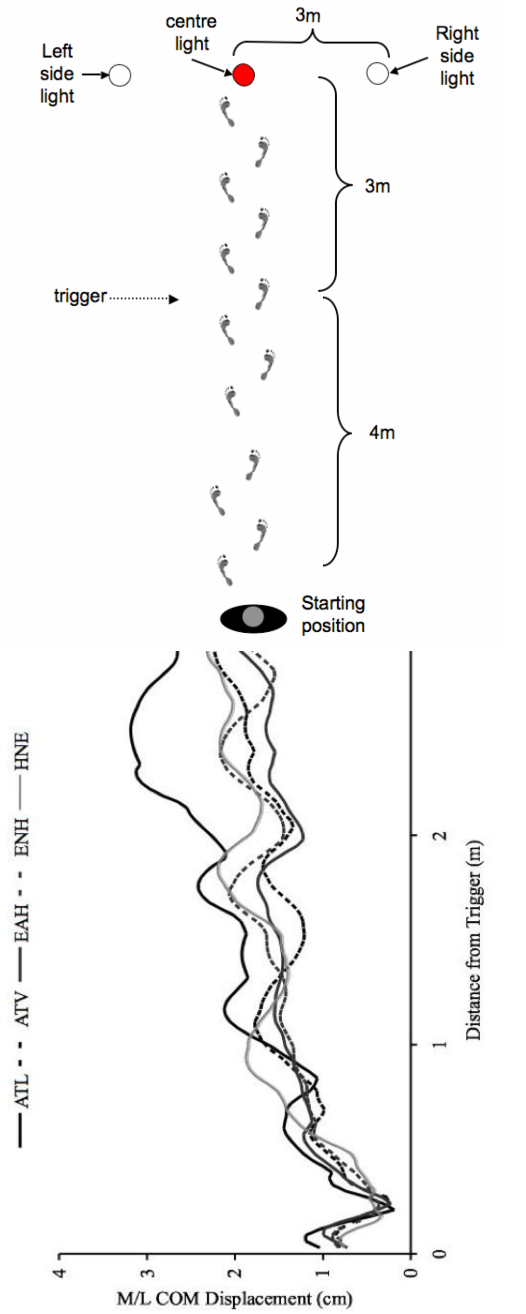

Fig.1 Experiment Setup and Results

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O.51

Coordination of turning while walking in individuals with Parkinson's disease "off" and "on" medication

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INTRODUCTION: Postural instability is one of the cardinal symptoms of Parkinson's disease (PD). Postural instability in PD is exaggerated in specific circumstances; e.g. individuals with PD show poorer balance and greater incidence of falls while performing specific tasks such as turning [1]. Difficulty turning is a sensitive predictor of the two key symptoms of PD locomotion: freezing and falling [2]. The association of turning with falls and freezing in individuals with PD emphasizes the importance of understanding the turning impairment in this patient population. The present study examined the effects of Parkinson's disease on the coordination of segment reorientation during different degrees of walking turns. The effect of dopaminergic medications on turning performance of individuals with PD was also examined.

METHODS: Fourteen individuals with PD, 7 M and 7 F, 67±4.8 years old, and nineteen age-matched healthy elderly volunteered to participate. The participants made 45° and 90° turns to their right in the middle of their walk on a 7 meter path. Kinematic data were recorded using four Optotrak 3D imaging system cameras (Northern Digital Inc., Waterloo, Ontario, Canada).

RESULTS: Segment coordination during the turns was similar for our PD participants ("off" and "on" medication) and healthy elderly. When turning, healthy participants reoriented their head first followed by simultaneous rotation of the shoulder and pelvis and lastly the mediolateral foot displacement. In PD participants, regardless of the medication condition, reorientation of body segments followed a top-down sequence with significant delay among the onset of reorientation of all body segments. The difference in the sequence of segment reorientation between the two groups was due to the significantly longer delay in the initiation of reorientation of pelvis in PD participants. Magnitude of the turn had no effect on the sequence and timing of segments' reorientation for either group. Our PD participants ("off" and "on" medication) differed from the healthy elderly with respect to the velocity of reorientation of body segments. At each magnitude of the turn, the peak angular velocity was significantly smaller for PD participants than for healthy elderly with the difference between the two groups being greater when larger angular velocity was required, i.e., during the 90° turns.

CONCLUSIONS: The lower peak angular velocities in individuals with PD could be due to bradykinesia. Alternatively, they may be the result of a compensatory strategy; individuals with PD may turn slower to produce less body angular momentum to be arrested at the end of the turn.

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O.52

Foot cutaneous stimulation during motor preparation enhances posture and locomotion components of step initiation in people with Parkinson's disease

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INTRODUCTION: Start hesitation (akinesia) and freezing of gait are often disabling symptoms of advancing Parkinson's disease (PD). External sensory cues can improve step initiation in PD including the anticipatory postural adjustments (APAs) for lateral weight transfer and forward propulsion. This study investigated the effects of electrical stimulation of the sural cutaneous nerve on the preparation, initiation and execution of rapid stepping in patients with PD. We predicted that applying sural nerve stimulation during the motor preparatory period would increase the magnitude of APAs and increase the speed of first step initiation.

METHODS: Eight subjects with idiopathic PD (Hoehn and Yahr Stage 2-2.5) were tested off medications. A pre-cue light instructed subjects to *prepare to step*, and was followed 2.5 s later by a "go-cue" light to initiate 3 rapid steps forward ((45 control trials (CR)). In 25 random trials, the right first step side sural nerve was electrically stimulated (1.5 X radiation intensity) at 1500, 1000, 500, 250, or 0 ms before the "go-cue"; ST1-5 respectively). Self-initiated (SI) stepping and cutaneous stimulation trials during quiet standing were also performed. APAs were characterized by ground reaction forces

(GRFs), net center of pressure (COP) changes (Fig.1), and EMG recordings. A rmANOVA with p<0.05 was used for data analysis.

RESULTS: Sural nerve stimulation frequently triggered the APAs during the preparatory time period prior to the visual "go-cue." As measured by the GRF and COP profiles, the incidence of APA initiation ($p < 0.05$) and the magnitude of the APAs ($p<0.001$) increased as the stimulus timing approached the "go–cue." APAs for SI trials were smaller in magnitude compared with CR and ST5 trials ($p=0.051$). Relative to APA onset, ST5 trials showed decreased ($p < 0.05$) time to first step toe-off compared to SI trials.

CONCLUSIONS: When applied prior to or together with a visual "go-cue" to initiate rapid stepping, sural nerve stimulation frequently triggered the early release and increased the magnitude of APAs as stimulation approached the "go-cue", indicating a progressive build-up in motor preparation.

There was also a quicker release of the APA-step sequence compared to SI stepping, and a trend towards differences in APA magnitude between SI and cued conditions. Cutaneous stimulation during movement preparation provides a novel therapeutic approach to enhancing step initiation in patients with PD. The results emphasize the importance of task instruction and movement preparation prior to stepping.

ACKNOWLEDGEMENTS: Supported by NIH grant RO1NS0541999 to Colum MacKinnon.

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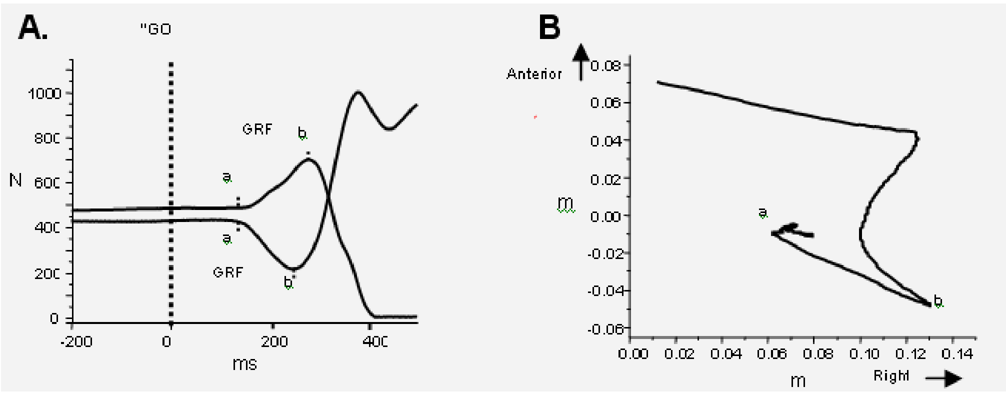

Fig.1 Representative quantification of APA characteristics. A.) Onset (a), duration (a-b), and magnitude (b) of the first stepping (R) leg GRF (loading) and single stance (L) leg (unloading); and B.) Rightward and posterior displacements (a-b) of the net COP.

O.53

Video recording of real-life falls in long term care provides new insight on the cause and circumstances of falls in older adults.

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INTRODUCTION: A major impediment to the design and evaluation of fall prevention strategies is our inability to obtain objective data on the incidence, cause, and circumstances of falls in real life. Instead, our current understanding of "how falls occur" is based on studies that report the post-hoc recollection of the faller [1,2], which is known to be of limited accuracy. These studies suggest that slips and trips are the most common causes, and that walking is the most common activity associated with falls in the elderly. In the current study, we tested whether this describes the scenario for most falls in long term care, by analyzing video recordings of 81 falls from two long-term care facilities in the Vancouver area.

METHODS: All 81 falls occurred in common areas and were captured with networks of digital video cameras (Figure 1). A team of three experts reviewed each fall recording to determine the primary cause and activity of the individual at the time of the fall. The experiment was approved by the Office of Research Ethics at SFU.

RESULTS: Only 15% of falls were caused by tripping and 5% by slipping; the most common cause (32% of cases) was incorrect weight transfer (Table 1). 28% of falls occurred during standing, 15% during forward walking, 14% while initiating walking, and 12% while moving from standing to sitting. Backward falls were more than twice as common as forward or sideways, and head impact occurred in 28% of cases. Furthermore, 36% of falls involved stepping and 24% involved grasping in an attempt to recover balance or minimize the impact of the fall.

CONCLUSIONS: These results challenge traditional assumptions regarding the nature of falls in older

Fig.1. Two of the 81 real-life falls analyzed in the current study

adults, and have important implications for the design and evaluation of fall prevention strategies targeting intrinsic and/or environmental factors.

ACKNOWLEDGEMENTS: Community partners DeltaView and New Vista care facilities.

	Frequency
Incorrect transfer/ shift of body weight	26
Trip/ stumble	12
Hit/bumped object or person	11
Collapse/ loss of consciousness	8
Loss of support with external object	5
Slip	4
Can't tell	15
TOTAL	81

Table 1. Causes of falls

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O.54

Determinants of disparities between perceived and actual fall risk in older people

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INTRODUCTION: Determinants of fear of falling in older people have been investigated in many previous studies [1]. However, the problem of inappropriate fear (either excessive or insufficient) that is not related to actual (physical) risk has not been studied [2]. This study investigated physical and psychological factors that account for disparities between perceived risk of falling (assessed with a falls efficacy scale) and actual falls risk (assessed with a test of postural sway).

METHODS: 500 community-dwelling older people (age 70-91) took part in the study. At baseline, participants completed assessments of physical functioning, activity levels, health status, risk-taking behaviours and neuropsychological performance. Postural sway was measured as displacements of the body at the level of the pelvis while standing on a foam rubber mat with eyes open. Fear of falling was assessed using the Falls Efficacy Scale International (FES-I) which provides information on concern about falls for a wide range of activities of daily living. The standardised residual for the regression of FES-I with sway was used as the measure of disparity between actual and perceived falls risk. Participants were followed up monthly for falls and 3-monthly for concern about falls over a 1-year period.

RESULTS: In the follow-up period 113 people (22%) fell 2+ times and 181 people (36%) indicated a high concern about falling.

a. Baseline sway and FES-I measurements were both significant predictors of multiple falls (OR=1.61 (1.09-2.38), p=0.017 and OR=1.52 (1.05-2.19), p=0.025 respectively).

b. Perceived-actual falls risk disparity also predicted multiple falls (OR=1.39 (1.13-1.70), p=0.002). Post-hoc analyses indicated that those with excessive concern about falling had an increased risk for future falls (p=0.011), whereas those with insufficient fear of falling had no increased risk (p=0.700).

c. Perceived-actual falls risk disparity could be explained by a number of psychological and behavioural measures including perceived health ($F_{(1,487)}$=153.10, p<0.001), outlook on life by means of positive affect ($F_{(1,487)}$=15.83, p<0.001), executive functioning ($F_{(1,487)}$=9.83, p=0.002), and level of physical activity by means of planned walks ($F_{(1,487)}$=4.28, p=0.039). In each case, those with excessive concern scored poorly in the tests.

CONCLUSIONS: The findings indicate that an excessive concern about falling increases the risk of falls. This elevated concern appears to be related to less positive affect and reduced neuropsychological functioning. On the other hand, an underestimation of concern does not appear to increase the risk of falls. Having a low concern of falling and a positive outlook on life, irrespective of physical fall risk, appears not to lead to excessive risk taking and may promote an active and healthy lifestyle.

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O.55

Force-thresholds for stepping in young and older adults

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INTRODUCTION: Stepping is an important strategy by which the brain controls balance and prevents falls. Previous work has found inappropriate step responses to be significantly more prevalent in older people, and those at risk of falling [1,2]. Using position-controlled perturbation systems, velocity and displacement thresholds have been determined for non-compliant (stiff) perturbations. However, the level of force and compliance of the perturbation would also influence the "decision" to step.

METHODS: This study used (compliant) perturbations of controlled force, to examine the capacity of the balance system to mount an opposing force and determine individual's stepping thresholds. Subjects were connected to a motor via light cables instrumented with load cells that attached to a belt worn on the pelvis. The motor applied a step of constant force for 0.5sec and subjects were told to try not to step. Anterior perturbation thresholds were studied in 14 young and 15 older healthy adults. Lateral perturbation thresholds were studied in 16 young and 9 older healthy adults.

RESULTS: Significantly lower anterior force thresholds for stepping were found in older adults (72.7±20.0N), compared to young (81.1±17.6N), while controlling for body weight ($F(1,27)=4.28$, $p=0.049$). Lower lateral force thresholds for stepping were found in older adults (77.2±20.3N), compared to young (93.2±21.3N), although this was not statistically significant while controlling for body weight ($F(1,24)=2.32$, $p=0.142$). Significant associations were found between anterior force thresholds for stepping and quadriceps muscle strength ($R = 0.56$, $P = 0.003$), and postural sway while standing on foam ($R = -0.43$, $P = 0.027$). In older adults, a significant correlation was found between weight-normalised anterior stepping thresholds and a falls risk score based on sensorimotor performance tests [3] ($R = 0.62$, $P = 0.025$). In successful (non-step) trials, the young adult's approximated centre of mass (COM) position moved further towards the base of support border than older adults, for anterior and lateral perturbations (see fig 1). This approximated COM displacement was significantly associated with force thresholds for stepping ($r=0.597$), while controlling for body weight ($t=2.15$, $p=0.044$).

CONCLUSIONS: Less forceful perturbations are required to induce steps in older people. Stepping thresholds to anterior perturbations were associated with physiological factors suggesting that this force-controlled perturbation produces a response based on the state of the body and ability to generate an effective response. Those who withstand larger forces are more able to control their COM closer to the base of support border.

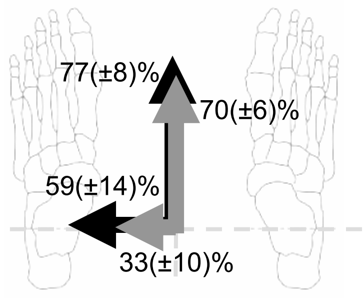

Fig.1 Arrow heads indicate maximum displacement (% of base of support border) of approx COM position in no-step trials for young (black) and older (grey) adults.

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O.56

Recurrent falls and dual-task related decrease in walking speed: is there a relationship?

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INTRODUCTION: A decrease in gait performance due to a simultaneously performed attention-demanding task has been reported [1]. Studies have shown that subjects with a history of falls present with more significant gait changes while dual-tasking than non-fallers [2]. However, the predictive value of dual-task related gait changes for recurrent falls remains uncertain. We hypothesized that changes in gait performance while dual-tasking might be related to recurrent falls in the elderly. The aim of this study was to determine whether dual task–related changes in gait speed were associated with recurrent falls in frail older adults.

METHODS: Counting backward performance while walking was investigated prospectively in a cohort of 213 older adults (mean age 84.4 ± 5.5) living independently in senior housing facilities. Usual and dual-tasking walking speeds ($m.s^{-1}$) were calculated on a 10-meter straight walkway at baseline. Information on incident falls during the follow-up year was collected monthly and participants were divided into 3 groups based on the occurrence of falls (0, 1 and ≥ 2). Recurrent falls were defined as ≥2 falls during the 12-month follow-up period.

RESULTS: Twenty subjects (9.4%) were classified as recurrent fallers. The occurrence of recurrent falls was associated with age (crude OR=1.11; P=.020), the number of drugs (crude OR=1.28; P=.002) and walking speed under both walking conditions (crude OR=0.96, P=.002 for usual walking and crude OR=0.60; P=.005 for walking while counting backward). Multiple Poisson regression showed that only walking speed while dual-tasking and the number of drugs were associated with incident falls (IRR=0.84; P=.045 and IRR=1.10; P=.004).

CONCLUSIONS: Decreased walking speed while counting backward was associated with recurrent falls, suggesting that changes in gait performance while dual-tasking might be an inexpensive way to identify frail older adults prone to fall.

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O.57

Predictors of recurrent falling in healthy older adults: the importance of both executive function and gait

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INTRODUCTION: Falls are a significant cause of morbidity and mortality in the elderly population. While falls are typically related to multiple factors including motor function and postural control, a growing number of recent studies have demonstrated that cognitive factors, especially executive function (EF), may also influence gait and fall risk and have shown that gait is not solely an automatic motor task, especially among older adults [1, 2]. However, the relationship between EF and fall risk in healthy older adults has been primarily investigated based on cross sectional and retrospective data. The aim of this study was to prospectively examine the relationship between EF, gait and fall risk, focusing on subjects who reported no falls in the past year.

METHODS: From a cohort of 264 healthy older adults, 203 adults (mean: 76.0±4.7 yrs; 60% women) who reported no falls during the twelve months prior to the study were investigated. Subjects were evaluated at baseline and again one year later. During the interim, they reported falls using monthly calendars. At baseline, all subjects were free of pathologies likely to directly affect gait. Subjects completed a computerized cognitive battery that generated an age and education-normalized index of EF. Based on the assessment of EF, the subjects with the upper (better) and lower (worse) quartiles were compared (n= 103). Clinical measures of mobility and fall risk included the Timed Up and Go test (TUG), Dynamic Gait Index (DGI), Berg Balance Scale (BBS) as well as gait under single and dual task conditions. Chi-square and t-tests were used for analysis between groups. Discriminant stepwise analysis assessed the predictive value of the outcome measures.

RESULTS: At baseline, all subjects had normal Mini Mental State Exam scores (MMSE mean=28.7±1.2; range 26-30), with no differences observed between the groups (p=0.15). Fifty-four subjects (26%) had index EF scores in the upper quartile (mean 111.8±4.9) and 49 (24%) were in the lower quartile (85±5.1). Small, but significant differences between the groups were observed at the beginning of the study in DGI (22.3±1.6 vs. 23.1±1.2; p=0.002), BBS (53.2±2.9 vs. 55.1±1.2; p<0.0001), and TUG (10.17±1.4s vs. 8.8±1.5s; p<0.0001) for the lower and upper quartile groups respectively, as well as comfortable gait speed (1.18±0.19 m/s vs. 1.34±0.23 m/s p<0.0001) and speed during dual task walking (p<0.0001). Swing percent variability (CV) was higher (worse) in the lower quartile group during gait under single task condition (3.1±2.3 vs. 2.3±0.7; p=0.027). In addition, 12% of subjects with lower values of EF had multiple falls during the one year follow-up, compared to none in the upper quartile group (p<0.0001). Discriminant analysis demonstrated that TUG, gait speed and DGI can explain 60.4% of the variance between the two EF groups.

CONCLUSIONS: While challenging gait assessment tools such as DGI and TUG may be used to predict future falls, the findings in this study suggest further that even in relatively healthy older adults, EF likely plays an important role in the risk for multiple falls. Although both EF groups had the same basic characteristics regarding MMSE and fall history at baseline (i.e., all subjects reported no falls prior to the study), individuals with lower EF scores were more prone to falls then individuals with higher cognitive scores, affirming the connection between cognition and fall risk. Apparently the transformation from non-faller to recurrent faller may involve altered EF.

ACKNOWLEDGEMENTS:

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O.58

Fall risk: prediction and prevention. Balance impairments in Indian subjects

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INTRODUCTION: Falls constitute a significant cause of morbidity and mortality. So far, prevention is the mainstay in the older and not so old population. Timely identification of underlying causes and intervention helps in formulating a designer program for individual management. The study was designed to investigate falls from all causes in 100 subjects. It first attempts to identify 1) Fallers from Non-Fallers, 2) Compares clinical methods to Computerized Dynamic Posturography (CDP) for testing [1] and 3) in particular it seeks to evaluate if it is possible to predict tendency to fall thereby offering preventive strategies before falls happen. This is feasible if we can assign precisely the cause i.e. failure from among the three physiological sensory balance mechanisms: Somatosensory, Visual and Vestibular.

METHODS: In studies for balance disorders until now we have been using the Berg Balance Scale (BBS) and the Dynamic Gait Index (DGI) as the Gold Standard. These clinical tests administered to all 100 subjects showed very good correlation between obtained scores and fall history as well as severity of underlying disease, but the limitations of the tests were that these are subjective, prone to inter-rater error and they do not differentiate between somatosensory, visual and vestibular affections and compensations. For refining the study a Basic Balance Master was obtained. Tests done on the Static Force Plate were: Limits of Stability (LOS), Modified Computerised Test for Sensory Integration of Balance (m CTSIB), Rhythmic Weight Shift (RWS), Unilateral Stance (US) and Weight Bearing Squat (WBS). Subjects divided into two groups of Fallers and Non-Fallers by clinical tests were tested on the Static Force Plate.

RESULTS: On comparison and correlation by Pearsons 'r' coefficient it was found that "sway velocity", "direction control", and "Center of Gravity" parameters have definite positive correlation between the two methods. We made a number of inferences: Age related changes in the cerebellum lead to asymmetric weight bearing, reflected by changes in WBS. Vestibular loss pattern is commonly seen by inability/difficulty in reaching posterior LOS. Unilateral stance is almost always low in the Indian population above 55 years, probably due to lifestyle pattern of floor level activity therefore low COG. Good in sitting, unstable on "sit-to-stand". mCTSIB picks up impending diabetic neuropathy, sometimes even before clinical diagnosis by somatosensory dysfunction pattern [2]. A unique "scatter" pattern of COG emerged in patients who had organic eye disease. Many who were unaware of their problem, on investigation turned out to have various kinds of visual (including cortical perception) problems. We have not come across this relationship reported elsewhere. Longstanding CNS disease patients with abnormal read outs surprisingly had history of few falls in ADL as they probably had spontaneously instituted compensatory mechanisms.

CONCLUSIONS: Consistently abnormal results were obtained in affected subjects in all tests administered by CDP. In addition it was possible to interpret whether the disturbance was somatosensory or visual or vestibular or a combination or none of these. Thus it was superior to clinical methods. A number of patients presenting merely for unsteadiness or for diseases such as diabetes mellitus or CNS disease were tested proactively and showed clear cut deviations from normal in the absence of history of significant falling. Since the pathology is pinpointed, individualized corrective or compensatory strategies can be offered. We used to very good effect the Cortico-Subcortical Relay theory, developed in our institute, to suggest appropriate alternative treatment approaches.

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O.59

Avoid alcohol, avoid falling?

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INTRODUCTION: Alcohol is a commonly used social drug and a well-established risk factor for accidents [1]. It is known to impair attention and information processing, even in lower blood alcohol concentrations (BAC). With increasing BAC, motor control declines as well. These factors combined, it is likely that alcohol use increases the chance of falling. However, it is unknown whether low BACs can already increase fall risk.

METHODS: Thirteen middle-aged participants performed two tasks: obstacle avoidance (OA) and manual reaction time (MRT). The participants were instructed to avoid obstacles (30 trials) while walking on a treadmill at a fixed velocity of 3 km/hr. In addition, 15 trials were done in a dual task condition (a modified Stroop task). The 2 tasks were performed 3 times, always following ingestion of a drink (first placebo, then 2 made up of 40% vodka mixed with orange juice). A breathalyzer was used to determine the BAC before, during, and after the experimental tasks. We aimed to reach a BAC of 0.8-0.9mg/mL 30 minutes after the final drink, using the Widmark formula to individually adjust for gender and weight. Both onset latency of the m. biceps femoris (prime mover involved in avoidance reaction) and failure rate in OA were assessed for 3 categories of time between obstacle detection and the estimated moment of foot contact with the obstacle (available response time, ART). By means of logistic regression a model was created to calculate the probability of failing OA, using failure as dependent, and ART and BAC as independent variables.

RESULTS: Figure 1 shows the probability of failing obstacle avoidance with increasing BAC for 3 ART categories. Note that even in lower BACs this probability strongly increases for the shortest ART. A strong correlation was found between BAC (up to 0.6mg/mL) and onset latency in the m. biceps femoris (after placebo, median: 158.3ms; after final drink: 183.9ms; $r=0.72$, $p<0.001$), with longer reaction times for increasing BACs. In the dual task condition, the chance of failing OA doubled significantly compared to the single task condition (OR=2.1, $p=0.0011$). No interaction effects between the two tasks and BAC were found. Furthermore, simultaneously performing a dual task resulted in significantly higher onset latencies (single task, mean(SD): 167.9(±18.6)ms; dual task: 191.3(±24.1)ms). The difference in onset latency between single and dual task (23.2(±14.1) ms, $p<0.001$) did not correlate with BAC. Manual reaction time increased significantly with 8%, with BACs up to 0.7mg/mL (after placebo, mean(SD): 255.7(±35.3)ms; after final drink: 276.6(±36.9)ms, $p<0.001$).

CONCLUSIONS: Alcohol impairs OA and MRT. The increase in MRT is in line with findings of previous research [2]. Yet, reaction time and failure rate in OA after ingestion of alcohol have never been studied before. Already at low BACs, the deterioration of reaction time may increase the risk of falling, especially at short available response time. Concurrently performing a dual task presumably adds to the risk of falling.

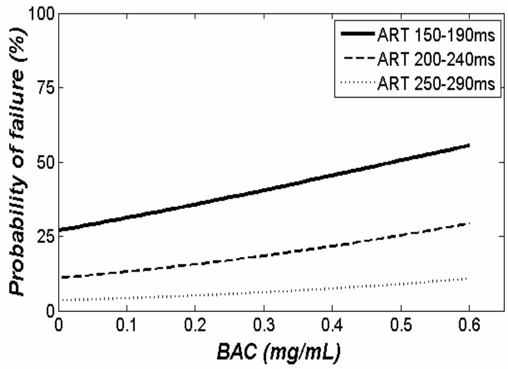

Fig.1 Probability of failing obstacle avoidance in a single task condition with short to moderate available response time (ART) while influenced by alcohol.

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O.60

Perception-action integration strategies for visually-guided locomotion in healthy vs spastic diplegic children, as revealed by kinematic data and trajectory analysis

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INTRODUCTION: Growing evidence is pointing to perceptual and cognitive factors determining many aspects of motor performance in various tasks. As to visually-guided locomotion, some invariant behaviours have been demonstrated in healthy adults, e.g. for gaze and head orientation, trajectory formation and velocity profiles, consistent with sensorimotor optimization strategies [1-3]. So far, little is known on the developmental course of such strategies and nearly nothing on their possible alterations in children with cerebral palsy. Aim of the present study is to describe gait patterns, trajectories and heading behaviours during visually-guided locomotion under different cognitive and perceptual conditions in spastic diplegic children and age-matched controls.

METHODS: Subjects: all spastic diplegic subjects admitted to our rehabilitation centre from Sept 08 are enrolled. Inclusion criteria: age = 7÷18 years; IQ > 70; independent walking. Age and gender-matched healthy controls are also recruited. Task: to walk straight to a marked tile (turning point), then to reach one of three targets: a central, a left and a right one. The target to be reached is automatically illuminated, either at the start or at the turning point ("LPre" and "LPost" conditions). Moreover, the subject may either walk alone or be accompanied by the light touch of a therapist on the back. Targets and conditions are randomized in a 3x2x2 design and every combination is repeated three times, for a total of 36 trials. 3D positions of light-reflective markers are recorded using an optoelectronic SMART-BTS motion-capture system wired to 9 cameras at a 120-Hz sampling frequency. Gait kinematics, heading orientation and the trajectory of the Centre of Mass (CoM) are extracted.

RESULTS: Preliminary data are available (two children with CP and one control): in the LPre condition both CP subjects and the control show anticipatory head orientation, as described by Grasso et al. [1] In the same condition, CP subjects tend to miss the turning point, while in the LPost condition they tend to overshoot it and the head orientation behaviour is disorganized. The light touch seems to help one CP subject but is irrelevant to the other.

CONCLUSIONS: Experimental setting was able to quantitatively analyze the spatial organization of goal-oriented locomotion in cerebral palsied children and its modulation by cognitive and perceptual conditions. Recordings and analyses of more subjects are needed to draw any conclusion, and contribute to better understanding of perception-action integration in locomotion and its disorders, which are often underlying apparently motor impairments.

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O.61

Anticipatory postural control in the diplegic forms of cerebral palsy: influence of the perceptive impairment

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INTRODUCTION: Children with Diplegic Infantile Cerebral Palsy (dICP) frequently show functional disabilities which cannot be ascribed to motor dysfunctions but rather directly to an impaired movement perception. This Perceptive Impairment (PI) entails the failure of a complex multisensory process involving the proprioceptive, visual, somaesthetic, and vestibular systems [1]. Children with PI recurrently show the following signs: i) exaggerated and low threshold startle reaction, ii) freezing posture, iii) blinking or closing eyes, iv) visual attention shifting, and v) facial grimaces. Postural adjustments depend on motor reactions as well as on perception, but perception has a leading role in anticipation [1]. We aimed to investigate how PI negatively influences Anticipatory Postural Adjustments (APAs).

METHODS: 25 children with dICP were selected (aged 6-14 years; acquired walking; no significant differences at GMFCS; no major sensory or cognitive deficit). 13 were diagnosed positive for PI, according to the mentioned clinical signs; 9 asymptomatic children participated as control group (aged 7-10). The experimental setting consisted of a functional reach and touch task from a sitting position; a force platform (Bertec 4060A) registered the centre of pressure trajectories. A small ball target was positioned at a distance of 120% and 140% of the arm length, laterally and frontally with respect to the dominant hand. APAs onset were identified by an opposite shifting of the COP during the initial phase of the gesture (2 SD higher than the baseline value) with respect to the reaching direction. The Angle Error (AE, being the angle between the reaching and the APA direction Fig. 1a) and APA Magnitude (M, [2]), were calculated on the detected APAs. The effects of direction, distance and diagnosis were tested with 3-way ANOVA. The post-hoc Bonferroni test was then used for multiple comparison ($\alpha=0.01$).

RESULTS: The target was touched in the 55%, 73% and 97% of the cases for PI, non-PI, and CTRL groups, respectively. The onset of APAs, AE, and M values among groups and directions are summarized in Fig. 1b, 1c and 1d respectively. For each of the 3 parameters, ANOVA highlighted an effect of the diagnosis ($p<0.01$) and of the target position ($p<0.05$), but no significant effect of the target distance ($p>0.05$). PI group showed fewer onset of APAs and larger AE with respect to the non-PI and CTRL groups, and lower values of M with respect to non-PI.

CONCLUSIONS: The PI negatively influenced the anticipatory control system: the anticipatory strategies of children with PI resulted ineffective. As compared to non-PI and CTRL, they rarely recruited APAs, each of which characterized by low magnitude and inaccuracy in directions. This resulted in a major difficulty in touching the target, thus in a low autonomy level in action. These data suggest that the functional capability of the dICP children could be severely reduced by the presence of the PI.

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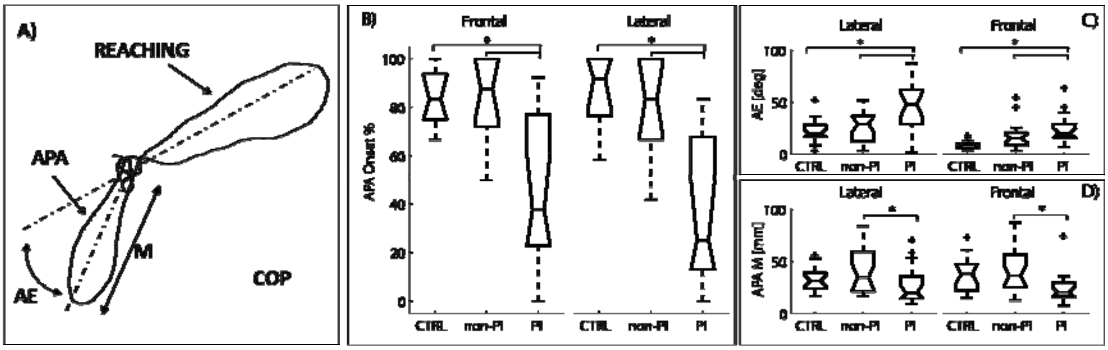

Fig.1a) Tipycal CoP trajectory; 1b) APAs onset; 1c) AE; 1d) M. * p<0.01

O.62

Relationship of dynamic standing balance and functional and temporal-spatial measures of gait in children with and without cerebral palsy

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INTRODUCTION: The development of walking is a major focus of paediatric rehabilitation. Interventions typically focus on improving standing balance to improve walking ability, in children with cerebral palsy (CP). Evidence that these skills are related has been limited, in part due to the poor relationship of static balance and gait. The primary objectives of this investigation were to 1) determine the relationship between functional walking level (e.g. Gross Motor Classification System (GMFCS)) and dynamic balance, and 2) compare dynamic balance and temporal-spatial gait measures in children across GMFCS levels.

METHODS: Twelve subjects (3 typically developing and 9 with spastic diplegia CP) participated, grouped by GMFCS. Dynamic balance was measured as maximum forward displacement at the shoulder and pelvis (cm) (displacement measure), normalized for height, and center of pressure excursion (COPE) (cm) using a force platform[1]. Subjects stood barefoot on a force platform with a symmetrical, self determined stance width, and were instructed to lean as far forward as possible, when cued. Five, 10 second trials were completed: three with arms crossed at chest level and two with arms extended forward. EMG recordings of leg and trunk muscles were recorded concurrently, and all trials were videotaped. Temporal-spatial gait data (i.e., velocity, cadence, step and stride length, step width and percent single leg stance time) was collected via video motion analysis at a sampling rate of 180 Hz as each subject walked barefoot down a 6.2 meter walkway without the use of assistive devices at a "self-directed pace"; three trials completed.

RESULTS: A moderate inverse relationship between GMFCS level and dynamic balance measures with arms in the forward position was found: COPE $r = -0.739$, $p = 0.007$, and clinical measure $r = -0.886$, $p < 0.001$ (Figure 1). The muscle pattern used was proximal to distal, with the ankle/hip ratio less than 1.0 in all but the GMFCS level 0 group. Significant group differences were found with walking velocity ($t= 1.806$, $p= 0.036$) and cadence ($t= 1.806$, $p= 0.057$) (Figure 2).

CONCLUSIONS: This investigation established the relationship between dynamic balance and functional walking level, and use of immature muscle activation patterns in those with decreased walking ability. The results suggest that use of interventions that promote changes dynamic balance ability and/or temporal-spatial walking characteristics may result in changes in level of functional walking ability.

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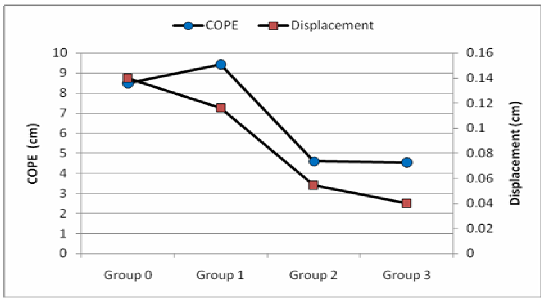

Fig. 1: GMFCS group means for dynamic balance measures

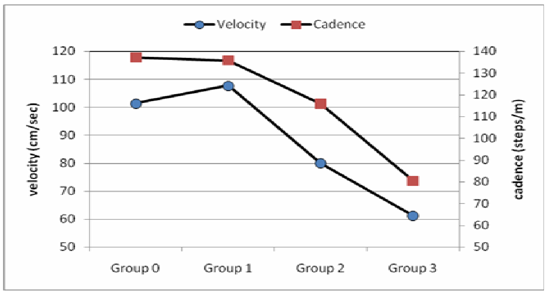

Fig. 2: GMFCS group differences: velocity and cadence

O.63

Physical activity patterns in children with cerebral palsy

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INTRODUCTION: Health problems related to inactivity in children from industrial countries are being increasingly investigated [1,2]. Earlier research concerning children with cerebral palsy (CP) has focused on the quality rather than the quantity of movements. The goal of this study was to quantify the level and patterns of physical activity in everyday life for children with mild CP, and to compare these results with both the activity of healthy children and the Swiss recommendations for daily activity of children.

METHODS: The activities of six 10-12 years old children with mild hemiparesis (4 boys / 2 girls) due to CP (GMFCS Level I) were logged, wearing an uniaxial accelerometer (ActiGraph, ActiGraph Pensacola/USA) on the hip of the non-affected side for one week during the day. Healthy children (n=37, age 10-12 years) served as the age matched control group. By means of the acceleration data, the total physical activity, the total duration of different intensity levels and the number of continuous sequences (5, 10, 15, 20min) in at least moderate intensity were determined. Activity levels were determined according to literature data [3].

RESULTS: The analysis of the total activity (counts per minute) over one week showed no difference between the groups (p=0.92). A within-group analysis comparing the weekdays with the weekend showed no difference in children with CP (p=0.79), whereas healthy children showed a trend to be significantly less active on the weekends (p=0.08). The average number of active minutes in the children of the study group was 70.6 min/day vs. 73.9 min/day in the control group. On a whole both groups spent the same amount of time in moderate (32.6 min in children with CP vs. 35.9 min in healthy children; p=0.53) and vigorous activities (38.0 min in both groups, p=0.99). A significant reduction in vigorous activity on the weekend compared to the weekdays was shown in both groups (p=0.05 and p<0.01, respectively). Continued sequences with at least moderate activities lasting 10 min or more were detected less than once per day and child; most sequences lasted less than 5 min.

CONCLUSIONS: We conclude that children with mild CP show similar activity levels and durations as a healthy control group. Both groups move sufficiently to fulfill the Swiss recommendations of daily activity which are set to 60 min/day of at least moderate activity. However, as the recommendations include continued sequences of at least 10 min duration, they are fulfilled only regarding total duration. This study justifies more research to investigate the activity level of children with different diagnoses and degrees of disabilities to substantiate our findings and to, in the long run, develop recommendations adapted for children with motor disabilities. In addition, research has to be done to investigate the impact of short duration activities on children's health.

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O.64

Bilateral deficit and EMG activity during explosive lower limb contractions with different overloads

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INTRODUCTION: The force developed during maximal voluntary isometric contractions (MVC) with both limbs (BL) is generally smaller than the sum of the forces developed separately by the two limbs (ML). The bilateral deficit (BLD) is defined as follow:

$$BLD = \frac{ML_R + ML_L - BL}{ML_R + ML_L} = 1 - \frac{BL}{ML_R + ML_L}$$

where $_R$ and $_L$ indicate the right or left limb.

BLD ranges from 0.20 to 0.32 [1] and is generally attributed to a lesser central activation of the individual limb when activated simultaneously with the controlateral one. The aim of this study was to determine whether BLD: 1) is observed also during explosive lower limb contractions; 2) can be attributed to a reduction of neural drive and/or 3) to a different muscle coordination, and/or 4) to changes of the muscle force-velocity relationship.

METHODS: The experiments were performed on 10 volunteers during maximal explosive efforts of ~ 400 ms duration on a sledge ergometer. The pushes were performed with both legs, and with the right and left leg separately. Several loads (ranging from 25 to 200% of the subject's body weight) were applied randomly by an electric motor. Peak force (F, N), sledge peak velocity (v, m/s) and electromyography (EMG) of four right leg muscles (vastus lateralis (VL), rectus femoris (RF), biceps femoris (BF), gastrocnemius medialis (GM)) were recorded.

RESULTS: The average Fs exerted by the right (●) or left (▲) leg during BL or ML (○, △) are reported as a function of the corresponding v in Fig. 1, BL curves being different from ML ones (p<0.01). Right and left Fs, averaged over the six loads, were lower (p<0.01) when pushing with both legs (883±200 N and 918±141 N) as compared to the ML (1285±177 N and 1306±147 N), the corresponding BLD amounting to 0.30. Pushing times (ms) and v were not different between BL (438±48 ms; 1.34±0.37 m/s) and ML (460±48 ms; 1.33±0.24 m/s). There were no correlation between Fs and integrated EMGs (iEMG) of the 4 muscles. VL and RF iEMGs, as a % of MVC, were lower (p<0.01) in BL than in ML (74±28 vs 91±21% and 39±21 vs 56±28% respectively). Mean value of iEMG, expressed as % of maximal iEMG value of each contraction, was higher for VL and RF (at 25, 40, 55, 70 and 85% of pushing phase), and BF (at 55%) in ML than BL (p<0.05), thus suggesting a faster response in the former muscles. At 25, 40, 55, 70 and 85% of pushing phase, the sum of the iEMG differences among the muscles (|VL-RF|+|VL-BF|+|VL-GM|+|RF-BF|+|RF-GM|+|BF-GM|) was higher in BL than in ML (p<0.01).

CONCLUSIONS: The force developed, at a given v, is significantly larger in ML, thus showing that BLD occurs also during explosive pushes with the lower limbs. EMG data suggest that BLD could be due to the reduction of neural drive of VL and RF, and to the different muscle coordination of VL, RF and BF, the latter muscles being activated later in BL than in ML. Moreover, a better inter-muscular coordination seems to be present in ML.

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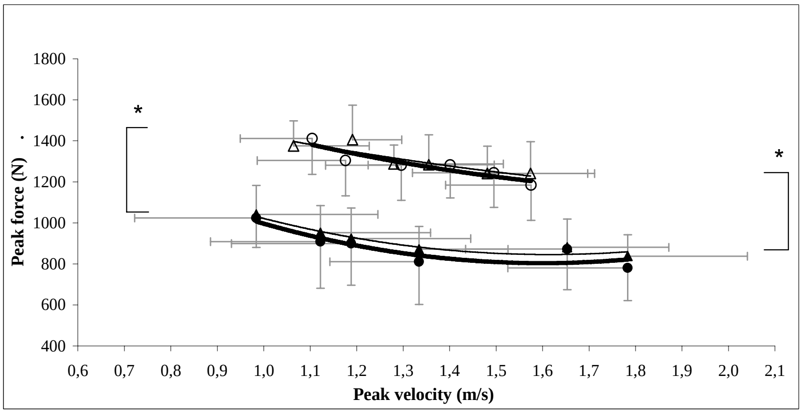

Fig. 1. "F–v" relationships during BL and ML explosive contractions of right and left leg

O.65

Spinal posture in sitting: How do we sit and how should we sit?

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INTRODUCTION: Clinical ergonomic advice for 'correct' spinal posture in sitting has been inferred from anthropometry theory and physiology studies. Qualitative observation of spinal posture has been used to argue that postures are too flexed, too extended, too static, too mobile, or require too little or too much muscle activity. Clinical advice for 'correct sitting posture' has advocated three different combinations of spinal curves in upright sitting. There is a lack of research evidence to quantify typical behaviour or to compare the clinically advocated postures. Studies that examine neuromuscular control in upright spinal postures rarely quantify the spinal position of their test subjects. Quantitative data for the spinal biomechanics and muscle activity are needed to examine 'how we sit'. Our studies quantified postural behaviour in sitting and the regional muscle activity associated with sitting postures that have been clinically advocated as 'correct'.

METHODS: A behavioural study examined spinal posture in three conditions (n = 50, 21 males): sitting for a 10 min computer task during which subjects were naïve to the purpose of the study, sitting in a manner subjects believed to be 'correct' for their spine, and relaxed standing. An intervention study with ten males examined whether subjects were able to imitate spinal curves in three sitting postures that have been clinically advocated as 'correct'. Regional spinal curves (thoracic, thoracolumbar and lumbar) and global orientation of the spine were measured with 3-D surface tracking. Regional muscle activity was examined in three upright sitting postures and a slumped posture. Healthy male subjects who had never suffered low back pain (n = 14) and males who had suffered recurrent low back pain but were pain-free at the time of testing (n = 10) were studied. Muscle activity was recorded from five regions of the spinal extensor muscles and four abdominal muscles with fine-wire intramuscular electrodes.

RESULTS: The behavioural study showed that spontaneous sitting posture during a 10 min computer task was flexed at the thoracolumbar [mean difference: 12, SD: (8) deg] and lumbar [24 (8) deg] spinal regions relative to standing. When subjects sat as they believed to be 'correct', they used a thoracolumbar angle similar to standing [1 (7) deg] but their lumbar angle remained flexed [16 (9) deg] relative to standing. When subjects attempted to imitate the three upright sitting postures that have been clinically advocated as 'correct', most subjects required facilitation in order to sit with spinal curves similar to standing (flat at the thoracolumbar region and lordotic at the lumbar region). Regional muscle activity showed that the three upright sitting postures that have been clinically advocated as 'correct' were associated with incremental changes in activity of the lumbar multifidus muscles. To achieve the same sitting postures, subjects with a history of low back pain showed greater incremental changes in activity at the longissimus thoracis muscle than healthy subjects did.

CONCLUSIONS: The results provide a new level of detail to quantify sitting postures that are common, postures that are achievable with facilitation, and differences in muscle activity between those with and without a history of low back pain. This provides a basis for clinical trials to examine whether particular postures and muscular strategies in sitting are advantageous. Changes in regional muscle activity associated with regional spinal curves in upright sitting suggest that future studies of spinal neuromuscular control may need to quantify or control regional spinal curves of their test subjects.

O.66

3D surgeons postural analyses during standard and robotic laparoscopic procedures

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INTRODUCTION: Laparoscopic surgical procedures offer the major advantage of mini-invasive access to patients. These techniques are therefore largely performed in all areas of surgery. However, they can put surgeons in uncomfortable posture, increasing more rapidly there muscle fatigue [1]. An other procedure now used by some surgeons is telerobotics. Surgeons reported that this procedure seems to be less tiring for upper body muscles. The goal of this study is to investigate the fatigue experienced by surgeons for each of these two procedures during long lasting surgery.

METHODS: 23 surgeons (3 women and 20 men), aged 27 to 65 (mean: 41.5; sd: 10.8) took part in that experiment. Surgical conditions were as close as possible to clinical ones; the only difference lies in the fact that the "patients" were pigs. Four surgeon postures were recorded during 80 minutes: one while they proceeded by telerobotics (Da Vinci, Intuitive Surgical®) and three while they proceeded by standard laparoscopy (pelvian, retroperitoneal or upper abdominal surgeries). Electric muscle activity (flexor digitorum, extensor digitorum, trapezius, erector spinae) was recorded by surface EMG, and whole 3D body posture was recorded with an optoelectronic system (Vicon®). Hip and shoulder joint centres were computed trough Hanavan model. 3D trunk position was analysed by distance measurement between hip and shoulder joints and torsion angle between shoulder and hip planes.

RESULTS: Preliminary results showed in both EMG and kinematics analyses, that the most important trunk involvement was observed during standard laparoscopy and more particularly when performing pelvian surgeries. Regarding kinematics analyses results (N=5) this intervention required a important trunk torsion (up to 15 d°) worsened by a large shoulder level unbalance (up to 70 mm). On the opposite, during telerobotics' intervention trunk torsion was inferior to 5 d° and shoulder horizontal level quite balanced (less than 20 mm). Regarding EMG analyses results (N = 11) EMG activities were also less important ($p<0,05$) during telerobotic surgery than during standard laparoscopy. These results will have to be confirmed by further analyses performed on the data obtained for other surgeons (need for statistical power).

CONCLUSIONS: As expected and as reported by surgeons, telerobotics surgery seems to be the less physically demanding situation, since it allows more comfortable positions. Minimizing the fatigue can have an important impact as for long lasting procedures.

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O.67

The effects of a load on balance during lateral load transfers.

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INTRODUCTION: Falls to the same level in the workplace are one of the leading causes of occupational injury and time loss from work [1]; even more so for manual material handling (MMH) occupations [1]. The U.S. National Institute for Occupational Safety and Health has a standard for MMH to maintain safe back loads [2]. However, no such standard exists for maintenance of balance during MMH. Without such standards an individual is left to make self-determined appropriate adjustments to maintain balance. While holding a lateral load above the body centre of mass (COM) has been shown to adversely affect balance [3], a dynamic lateral load transfer has yet to be studied. The purpose of this study was to investigate balance during lateral load transfers. We were particularly interested in the likelihood of a fall due to load.

METHODS: Eight healthy individuals without MMH experience performed lateral load transfers with a box weighing 5% of body weight and an unloaded box of exactly the same dimensions. The independent variable was load condition. Transfers were from 90° on one side of the body to the same distance 180° around to the other side of the body. Loaded box distance was set to the maximum the participant identified that could be safely accomplished after at least 6 practice trials. Unloaded transfers utilized this same distance and a new practiced safe maximum distance. The box transfer occurred to and from two pedestals adjusted such that the box handholds sat at standing elbow height. Instructions specified not to lift a foot completely off the floor. The movement of the COM within the base of support (BOS) defined the metric for balance. COM was calculated from the individual segment masses using a 13-link model of the body plus one box segment when acquired. Segment masses and BOS markers were identified using a 12-camera passive-marker motion-analysis system The BOS was measured at each frame using four markers on each foot and accounting for toe and heel lifts. Dependent variables were the COM path variability (COMpv), the minimum distance of the centre of gravity to the edge of the base of support (COG-BOS), the time of the COG-BOS and the number and types of balance loss. A mixed model ANOVA was used for statistical analyses.

RESULTS: COMpv was ~10% greater during the loaded transfer compared to the both unloaded transfer conditions ($p<.0001$). Surprisingly, COG-BOS variables were not statistically different between loaded and unloaded tasks ($p=.4684$). In both tasks COG approached the edge of the BOS. Frequently, this occurred as the load was picked up and while the participant had both heels raised off the ground. Of the 6 trials where imbalance occurred (contralateral foot lifts and subsequent recovery), 5 were during the loaded condition and one during the unloaded conditions.

CONCLUSIONS: Two out of three balance measures indicate reduced balance control due to the load. COG-BOS results alone indicate that the additional load may not result in any greater likelihood of a fall. However, there were more imbalance trials during the loaded condition than the unloaded conditions. The COG-BOS measure may lack the precision to detect minute differences, which could be the difference between imbalance and maintained balance during this MMH task. In addition, the COMpv results indicate that the additional load leads to reduced control of balance and therefore, when transferring a load, recovery from an imbalance may be compromised.

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O.68

Sway jerk is a good biomarker of early Parkinson’s disease and its progression

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INTRODUCTION: It is not known yet whether spontaneous sway in quiet stance is somehow abnormal in people with early Parkinson's Disease (PD). Furthermore, it is not known if sway measures show changes that are correlated with the disease progression early in the disease process. Jerk, that is the rate of change of the acceleration, has been used in motor control studies to quantify smoothness of movement [1]. We hypothesize that jerk of trunk sway may be altered in early PD, and could provide a sensitive measure of disease progression.

METHODS: We examined 12 PD and 12 healthy, age-matched control subjects. PD subjects were newly diagnosed and were not taking any medications at baseline. All subjects were tested a second time 3-to-6 months after the baseline test (1^{st} measure), and a third time 3-to-6 months after the 1^{st} measure (2^{nd} measure). Those PD subjects who started dopaminergic medication were tested 'off'. Subjects were asked to stand still for 2 minutes staring at an art poster with eyes open. They wore a MTX Xsens inertial sensor, mounted with Velcro belts in the middle of the posterior trunk, at the level of L5. We computed several parameters from 2-D horizontal acceleration signals, including: RMS acceleration (RMS), sway velocity (MV), frequency comprising the 95% of the power (F95%), frequency dispersion (FD), and JERK. One-way ANOVA was used to test statistical differences between groups. A receiver operating characteristics (ROC) analysis was used to evaluate the discriminative value of each parameter. A Linear Mixed Models analysis was used to compare groups and follow-ups.

RESULTS: PD subjects had a larger JERK (Fig. 1A), RMS and FD ($p<0.05$) compared to control subjects. Also, PD subjects showed a reduced F95% ($p<0.05$), and comparable MV. ROC analysis (Fig. 1B) revealed an area under the curve of 0.98 for JERK, which was the highest discriminative value of all variables. In addition, JERK was higher, at the baseline, in those PD subjects that before the 1^{st} measure will start dopaminergic medication. Longitudinal testing showed that control subjects had consistent JERK across the three measures with little variability among subjects while PD subjects progressively increased their JERK until medication was started.

CONCLUSIONS: Our results show that changes in trunk sway, and especially an increase in JERK meaning a decrease in smoothness of movement, can be measured before clinically apparent in early, untreated PD subjects. Thus, JERK could be used as an objective measure of PD and its progression, e.g. in neuroprotection studies. Accelerometer-based analysis of spontaneous sway could provide a simple but sensitive tool to cope with mass screening of subjects at risk to develop PD.

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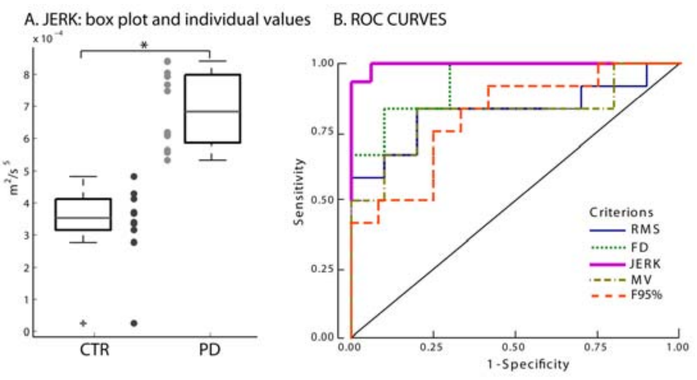

Fig.1 Sensitivity and specificity of postural measures

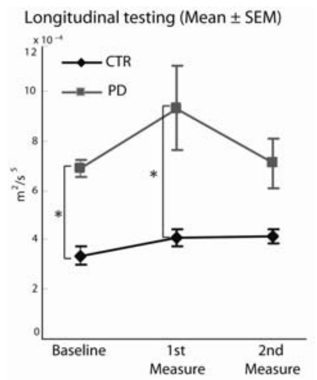

Fig.2 Longitudinal results

O.69

Lower limb kinematics during obstacle crossing in people with Parkinson's disease

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INTRODUCTION: Hypokinesia is a cardinal symptom of Parkinson's disease (PD) and often results in underscaled motion of the lower limb joints during level-ground walking [1]. It remains unclear how PD affects the lower limb kinematics of walking when stepping over ground-based obstacles. We investigated lower limb joint angles during obstacle crossing in people with PD compared to age-gender matched control participants to identify whether people with PD use different kinematic strategies during obstacle crossing.

METHODS: Obstacle crossing was observed in 18 people with mild to moderate PD (4 females; 65.5 ± 8.0yr; Unified Parkinson's Disease Rating Scale (Motor) 12.6 ± 5.4; Hoehn & Yahr stage range 1-3) and 18 age-gender matched comparisons (65.2 ± 8.8yr). Participants walked at a self selected pace for ten steps before stepping over an obstacle (height 10% of leg length x 600mm x 10mm). Sixteen trials were analysed for each participant. Eighteen retroreflective markers were taped onto anatomic landmarks of the lower limbs and pelvis of participants. Marker trajectories were captured using a Vicon three-dimensional motion analysis system (100Hz). The plug-in-gait model (Oxford) was applied to calculate lower limb and pelvic angles in the sagittal, frontal and transverse planes. Two-sided paired t-tests were used to compare dependent variables between the two groups.

RESULTS: When the lead limb was directly above the obstacle, people with PD had greater knee flexion (p < .001) and hip flexion (p = .003) for the stance limb, and greater hip flexion (p = .045) for the swing limb compared to control participants. There was also a trend for people with PD to have greater pelvic obliquity (p = .072), whereby they raised the swing limb more than controls. When the trail limb was directly above the obstacle, people with PD were in less hip adduction (p = .010) and tended to be in more knee flexion (p = .068) for the stance limb. Ankle dorsiflexion (p = .027) and hip flexion were greater (p = .006) for the swing limb. Those with PD had greater pelvic obliquity, whereby the swing limb was elevated more than controls (p = .001).

CONCLUSIONS: Some people with PD use a hip hiking strategy to increase foot clearance during obstacle crossing as a compensation for a more flexed position of the stance limb. Further investigation is warranted to examine whether people with PD who have hip abductor weakness or advanced hypokinesia pose a PD greater risk of tripping during obstacle crossing.

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O.70

Walking cadence and velocity is improved by rhythmic vibration of postural muscles in Parkinson's disease

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INTRODUCTION: Timed bilateral alternate vibration applied to homonymous leg or trunk muscles during stance produces cyclic medio-lateral transfer of the centre of foot pressure in normal subjects and Parkinsonian patients (PD) [1]. We have tested the hypothesis that muscle vibration with a similar pattern may have potential to improve walking in PD.

METHODS: Fifteen patients and 15 normal subjects walked on an instrumented walkway under four experimental conditions: no vibration (no-Vib), and vibration of tibialis anterior (TA-Vib), soleus (Sol-Vib) and erector spinae (ES-Vib). Trains of within-train 100 Hz-vibration were delivered at alternating frequency of 10% above natural step cadence.

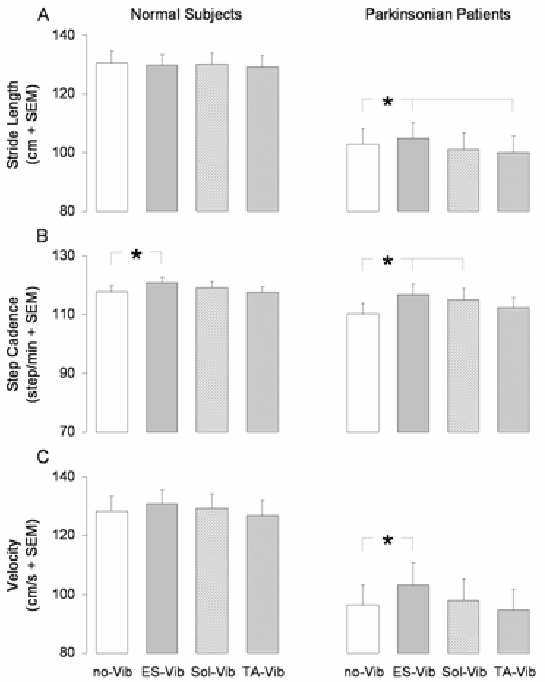

Fig.1 Changes in gait variables during alternate bilateral vibration of Sol, TA and ES with respect to no-vibration condition

RESULTS: Natural stride length and velocity were lower in PD than in normal subjects, while cadence was only slightly reduced. All patients increased walking velocity under vibration conditions. This was produced by increased cadence, and to a lesser extent by increase in stride length (Fig. 1). The findings were consistent across subjects and across patients and the effects were qualitatively similar in both groups. However, in the normal subjects, velocity was not affected to a significant extent, due to a smaller increase in step cadence, while stride length was unaffected. In PD, locomotion was selectively improved by ES-Vib, weak or no effects being produced by Sol-Vib or TA-Vib in both groups. On average, the velocity during ES-Vib increased by about 2% in normal subjects and 7% in patients.

During ES-Vib, patients attained a cadence not different from the spontaneous cadence of normal subjects.

CONCLUSIONS: Alternate ES vibration improves gait possibly by enabling the body medio-lateral shift that is impaired in PD due to deranged trunk control [2]. The effect of ES vibration might depend on the richness of spindles [3] and the importance of these muscles in steering locomotion [4].

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O.71

Auditory cueing and obstacle avoidance in Parkinson's disease patients

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INTRODUCTION: Parkinson's disease (PD) patients suffer from gait disturbances, leading to a characteristic hypokinetic gait, with e.g. a decreased stride length or freezing of gait (FOG). Rhythmic auditory cueing can facilitate walking in PD by lowering stride frequency while maintaining walking speed, resulting in an increased stride length. Cueing can also reduce FOG. However, improper cueing frequencies (either too low or too high for a given individual) may also aggravate gait disturbances and worsen FOG. Previous studies showed that the most efficient frequency to improve gait parameters in PD patients is the preferred cadence of the patient minus 10% [1]. In daily life, cueing might interfere as a dual task, when other tasks have to be executed simultaneously. For example, sharing attention between an obstacle avoidance task and a cognitive dual task resulted in decreased obstacle avoidance performance on the treadmill [2] and a lowered cognitive task performance during over ground walking [3]. The aim of the present study is to examine the interaction between walking with an obstacle avoidance task and the ability of subjects to synchronize their heel strikes to an auditory cue, and how both tasks affect each other when executed at the same time.

METHODS: We used 17 PD patients (H&Y stage between 1 and 2), of which 6 patients had FOG, and 15 healthy age- and gender-matched controls. All patients were tested in a practically defined 'off' state. The design included four conditions: normal walking, walking with a metronome set at -10% of preferred cadence for patients and +10% for controls, walking with an obstacle avoidance task, and walking with a metronome as well as an obstacle avoidance task. These conditions were recorded during both over ground walking and on a treadmill at 2 km/h. Main outcome measures included foot clearance (the vertical distance of the foot over the obstacle, as a measure of obstacle avoidance performance), metronome synchronization (the delay between heel strikes and the metronome), and kinematic gait parameters (walking speed, stride length, stride time and cadence). Differences between groups and conditions were compared using a one-way ANOVA. A Tukey's post-hoc test was conducted, corrected for multiple comparisons ($p < 0.05$ as significance level).

RESULTS: There were no differences in obstacle avoidance performance between both groups and the several conditions. Freezers and non-freezers showed the same results for all outcome measures. Controls adhered best to metronome synchronization during over ground walking ($p=0.009$). On the treadmill, metronome synchronization was worse compared to over ground walking for both groups. During obstacle avoidance tasks on the treadmill, metronome synchronization was better in controls, both in the steps just before ($p=0.011$) and right after ($p=0.012$) obstacle crossing. For patients, walking over ground with a metronome or with an obstacle avoidance task caused a decrease in cadence and an increase in stride time.

CONCLUSIONS: Overall, patients had more difficulties to synchronize their heel strikes to the metronome than controls. Auditory cueing did not affect obstacle avoidance performance in either group. The obstacle avoidance task also did not affect the performance on the metronome task in both patients and controls. However, on the treadmill, controls performed better on the metronome task than patients. This suggests that PD patients were able to prioritize prevention of stumbling above the metronome task, at the expense of less accurate adherence to the metronome task.

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O.72

Autonomic Nervous System in Parkinson's disease: New evidence on the relationship to Freezing of gait

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INTRODUCTION: Freezing of gait (FOG) is among the most disabling and least understood symptoms affecting patients with Parkinson's disease (PD). While the patho-physiology underlying FOG largely remains an enigma, there is some evidence suggesting that stress exacerbates and increases the likelihood that FOG may occur [1]. The reaction to stress is in part regulated by autonomic nervous system (ANS), as reflected in measures of heart rate variability (HRV) and heart rate average (HRA). Studies have already demonstrated decreased HRV in patients with PD, compared to age-matched controls [2-3], however, the possible contribution to FOG has not yet been examined. We hypothesized that HRV and HRA would behave differently in PD patients who experience FOG (PD+FOG), compared to those who do not (PD-FOG), and further, that among PD+FOG, ANS activity may be related to the occurrence of FOG.

METHODS: 15 healthy older adults, CO (mean age: 67.6±9.5 yrs 6 women), 10 PD-FOG (mean age: 66.4±5.7 yrs; 4 women) and 10 PD+FOG (mean age: 64.9±5.4 yrs; 4 women) were studied. Patients with PD were tested during their "off" state, 12 hours after the last anti-Parkinson medication was taken. HRA and HRV (i.e., beat-to-beat variability over 1 min windows) were measured using a 2 lead ECG as subjects carried out tasks used to provoke FOG during "off" (e.g., turning, stopping abruptly, walking at a fast speed). Data was analyzed in 3 conditions: standing, usual walking and fast walkig and between groups. Among PD+FOG, FOG episodes were analysed in intervals of 10 seconds before, during, and after FOG. HRA in 10 seconds intervals of FOG were compared to HRA in 10 seconds intervals of walking without FOG.

RESULTS: HRA increased ($p<0.0001$) between conditions in all groups (e.g., when going from usual walking to fast walking: CO: 16.2±4.6%, PD-FOG: 9.9±6.2%, PD+FOG 7.7±2.3%). The % change in HRA from one condition to another was lower in the PD subjects, especially in PD+FOG ($p=0.002$). HRV was lower ($p=0.001$) in PD patients compared to CO. HRV and HRA were not correlated with disease duration ($p>0.22$) but HRA was correlated with UPDRS-motor scores (e.g., HRA standing $r=0.58$, $p=0.01$). HRA was correlated with FOG severity (e.g., standing $r=0.47$, $p=0.05$; % change to fast walking: $r=0.59$, $p<0.01$), as measured by the FOG-Q. FOG-Q and UPDRS-motor were not correlated. Among PD+FOG, 120 FOG episodes were observed. HRA increased ($p<0.01$), by an average of 1.1 bpm, during FOG as compared to HRA measured 10 seconds before the beginning of FOG. HRA also increased ($p<0.0001$) by an average of 17.4±2.8 bpm during usual walking and 6.6±3.6 bpm during fast walking with FOG at turns compared to similar 10 seconds intervals of walking without FOG.

CONCLUSIONS: To our knowledge, these findings are the first to experimentally document the possible contribution of ANS dysfunction to FOG. In patients with FOG, HRA generally follows the same pattern as seen in patients without FOG and healthy elderly adults in response to different walking conditions**.** Nonetheless, the decline in HRV in patients with FOG suggests that the ANS system is impaired and reacts differently to changing conditions. The increase in HRA observed during FOG also supports the idea that FOG may be related to ANS function. It appears that ANS alterations might be specific to FOG and not a general by product of disease severity.

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O.73

Modulation of gait symmetry by subthalamic stimulation improves intractable freezing of gait

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INTRODUCTION: Freezing of gait (FOG) is a poorly understood gait disorder affecting more than 50% of patients with Parkinson's disease (PD). Gait is a complex multi-component motor process which amongst others requires precise coordination between both body sides. It has therefore been hypothesized that dysfunction in rhythmicity, symmetry or coordination between both legs might be an important risk factor for FOG [1]. It is yet unclear whether change of these variables by subthalamic deep brain stimulation (STN-DBS) influences the gait performance of PD patients. Aim of this study was to study how modulation of symmetry between both legs by STN-DBS impacts on FOG.

METHODS: We enrolled 22 consecutive PD patients (13 FOG+) with STN-DBS for at least six months. At time of examination mean age was 63.2 ± 7.7 (mean ± standard deviation), disease duration 15.2 ± 4.3 years, and follow-up after surgery 35.9 ± 32.2 months. After cessation of all dopaminerg medication, patients were evaluated in the following four conditions: STN-DBS on (DBS ON), STN-DBS off (DBS OFF), 50% reduction of stimulation voltage contralateral to the slower leg (worse side reduction, WSR), 50% reduction voltage contralateral to the faster leg (better side reduction, BSR). Gait analysis was performed on a motor-driven treadmill (Woodway, Germany) and recorded by three-dimensional opto-electronic analysis system (Qualisys, Sweden). We measured the frequency and duration of FOG-episodes during 40 sec of recording. The bilateral coordination of gait was assessed by the Phase Coordination Index (PCI) quantifying the phase between the left and right leg with lower values indicating more symmetric gait [2].

RESULTS: In FOG- patients, there was no effect of BSR or WSR on gait performance. In FOG+ patients, during DBS OFF, there were 2.0 ± 0.37 FOG episodes lasting for 12.19 ± 2.63 sec. During DBS ON, FOG significantly improved with reduction of episodes (1.38 ± 0.46) and duration (2.58 ± 0.81 sec) (P=0.005). During WSR, FOG worsened with increase of episodes (1.31 ± 0.41) and duration (5.23 ± 2.10 sec). Remarkably, BSR further improved FOG with significantly lesser FOG episodes (0.23 ± 0.23) and duration (0.21 ± 0.21 sec) compared to DBS ON (P=0.03) (Figure 1). During BSR, FOG reduction was accompanied by normalisation of symmetry as measured by PCI (16.5±6.0%) which was significantly lower than in the other three conditions.

CONCLUSIONS: In FOG+ patients, change of symmetry by STN-DBS significantly improves limb coordination and reduces FOG. This identifies poor leg coordination as a major risk factor for FOG which just be considered during adjustment of stimulation parameters.

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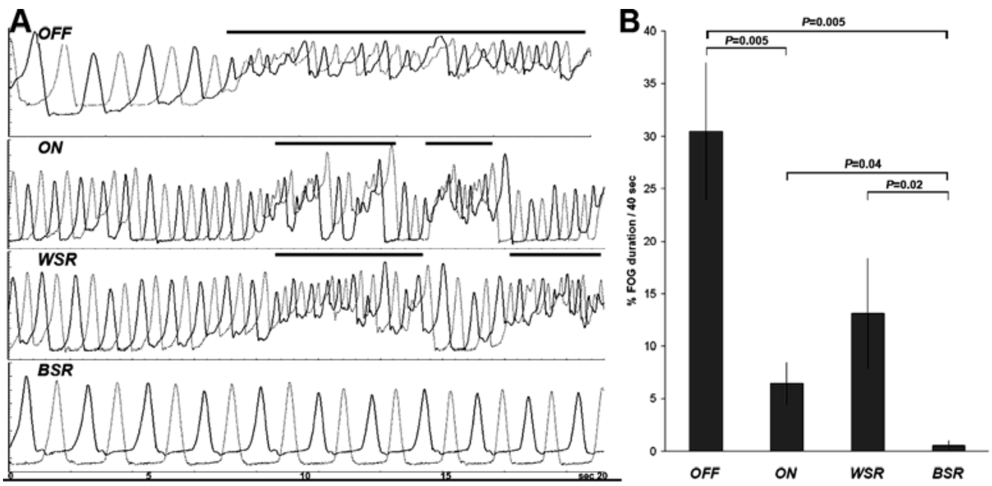

Fig.1 The trajectories for the two feet in a patient (A) and FOG duration (B) for the whole sample during the 4 conditions.

O.74

Monoaminergic and cholinergic correlates of falling in Parkinson disease

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INTRODUCTION: Parkinson disease (PD) is a neurodegenerative disease causing postural instability and disordered gait, leading to a higher rate of falls. Loss of striatal dopamine is believed to underlie these mobility problems. Dopamine replacement therapy, however, produces limited improvement in fall risk in PD. This implies that extra-striatal or non-dopaminergic deficits may play a role in postural instability and gait disorders in PD. We aim to identify differences between fallers and non-fallers in brain region specific cholinergic and monoaminergic pathways.

METHODS: 46 PD patients (11 F, 69.4 ± 9.6 yrs, 51-83 yrs, Hoehn & Yahr 1-3) underwent $[^{11}C]$DTBZ and $[^{11}C]$PMP PET imaging. $[^{11}C]$DTBZ binding is specific for the vesicular monoamine transporter 2 (VMAT2) and reflects integrity of monoaminergic terminals. $[^{11}C]$PMP is a substrate for acetylcholinesterase and reflects cholinergic pathway integrity. PET data were analyzed using standard PET imaging analysis techniques yielding estimates of DTBZ binding and PMP uptake. Fallers were identified from the 'Falling' item on the UPDRS (i.e. > 0). Binding differences in striatal DTBZ, thalamic DTBZ, thalamic PMP, and cortical PMP between fallers and non-fallers were statistically tested using MANOVA.

RESULTS: There were 19 fallers (41%). Fallers scored significantly ($p < 0.0001$) higher (1.5 ± 0.5) on the postural instability and gait disorder (PIGD) sub-score (from UPDRS) than non-fallers (0.8 ± 0.4). MANOVA showed brain region specific neurochemical effects between fallers and non-fallers ($F = 3.2$, $p = 0.023$). In particular, there was a difference in binding between fallers and non-fallers in the thalamus for both $[^{11}C]$DTBZ binding ($F = 6.0$, $p = 0.018$) and PMP uptake ($F = 5.2$, $p = 0.027$). $[^{11}C]$DTBZ binding was actually higher for fallers (1.25 ± 0.09) than for non-fallers (1.19 ± 0.06), while PMP uptake was lower for fallers (0.057 ± 0.006) compared to non-fallers (0.061 ± 0.007).

CONCLUSIONS: There was no significant difference between fallers and non-fallers in striatal monoaminergic (dopamine) terminals, while thalamic monoaminergic and cholinergic pathways were altered in PD fallers. The thalamus receives sensory information and afferents from the pedunculopontine nucleus, and plays an important role in posture and gait control. The thalamus is innervated by both monoaminergic (dopamine, serotonin, noradrenaline, and histamine) as well as cholinergic neurons. A change in these afferents probably changes the activity of thalamic neurons. Altered thalamic functioning may be more important in PIGD-related falls in PD than dopaminergic denervation of the striatum.

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O.75

Sensory integration for stance control involves perceptual inhibition in older adults

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INTRODUCTION: Maintaining balance and processing information typically interfere with each other for older adults, suggesting that executive functions may be engaged. One particular aspect of executive functions, inhibitory processes, is known to decline with age and has been implicated in aging's impact on postural control. The purpose of this study was to determine if measures of perceptual and/or motor inhibition are associated with postural control in healthy young and older adults.

METHODS: Twenty four young (mean 25 yrs) and 24 older adults (mean 74 yrs) with no history of vestibular or neurological disorders participated. Perceptual and motor inhibition were measured using a protocol adapted from [1]. The test measures button-push reaction times (RT) to visual stimuli on a computer screen including arrows pointing either to the right or left. Two types of RT tasks were presented in order to create a perceptual conflict and a motor conflict. These measures were then correlated to postural sway (RMS) collected during standing conditions on a dynamic posturography platform that required varying levels of sensory conflict, e.g. world-fixed versus sway referenced floor and visual scenes.

RESULTS: In the older adults, no significant correlations occurred for fixed floor conditions between perceptual inhibition and sway RMS; however, perceptual inhibition was positively correlated with sway amplitude on a sway referenced floor with fixed visual scene (r=.68; p<.001). (Fig. 1) There was no correlation between perceptual inhibition and sway in young adults. Motor inhibition was not correlated with sway for any conditions in either group.

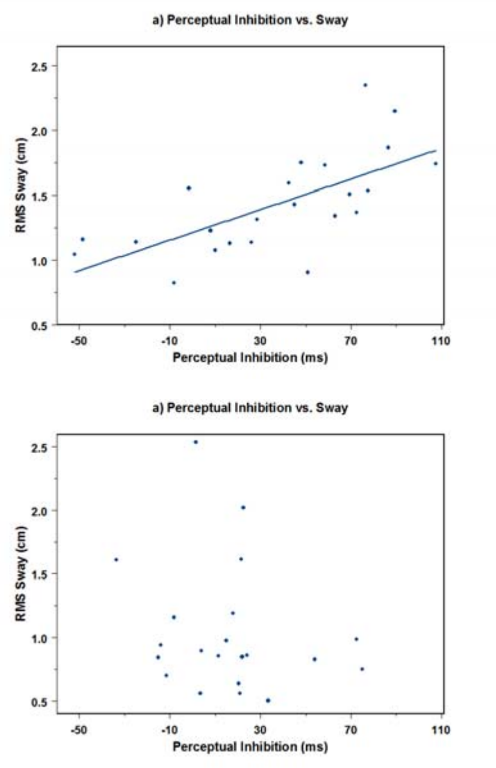

Fig.1 Perceptual inhibition versus sway RMS for older (top panel) and young (bottom panel) adults while standing on the sway referenced floor with a fixed visual scene.

CONCLUSIONS: Perceptual inhibition may be a component of the sensory integration process important for maintaining balance in older adults. The results suggest that "sensory reweighting", which occurs when ankle proprioception conflicts with visual information, appears to involve a perceptual inhibition of information from the proprioceptive system.

ACKNOWLEDGEMENTS: Supported by NIH through grants AG14116 and AG024827.

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O.76

Evidence for a link between inappropriate compensatory pitch head movement and increased obstacle contacts in older people wearing multifocal glasses

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INTRODUCTION: Previous research has shown that when wearing multifocal glasses versus single lens glasses, older people are at increased risk of tripping [1, 2] and display greater variability of foot clearance when negotiating a step [2]. Furthermore, when looking through the lower versus the upper segment of the multifocal glasses, distant depth perception and contrast sensitivity are reduced [1]. This study investigated whether older adults adopt compensatory head and eye movements when negotiating an obstacle course with or without a secondary task, when wearing multifocal versus single lens glasses.

METHODS: Thirty older adults (70 + years) performed 3 obstacle-only trials and 3 dual-task trials on a 17.5 m long obstacle path in multifocal and single lens glasses, at self-selected speed. The secondary task required subjects to look up and read aloud three letters from a computer screen positioned at eye-level at the end of the walkway. Eye and head movements were recorded using a video-based eye tracker and a gyroscope, respectively. Differences in head pitch angle (HA), amplitude of eye and head movement in pitch (PA-E and PA-H, respectively), trial time, obstacle contacts and letter errors were assessed between glasses conditions using Wilcoxon Signed Ranks Tests. Relationships among age and measured variables in the multifocal glasses condition were examined using Spearman correlations.

RESULTS: The participants performed the obstacle-only trials slower when wearing the multifocal versus the single lens glasses (P =.004). In the dual task trials, participants contacted more obstacles in the multifocal glasses condition (P =.001), however there were no significant differences in eye or head movement between glasses conditions. For the multifocal glasses in the dual-task trials, increased PA-E was associated with increased obstacle contacts (ρ= 0.409, P =.025) while increased PA-H was associated with increased letter errors (ρ= 0.538, *P* =.002). A lower HA was associated with an increase in letter errors (ρ= 0.548, P =.002) and PA-H (ρ= 0.455, P =.019). Finally, for the multifocal glasses condition, older age was associated with increased obstacle contacts in the obstacle-only trials (ρ= 0.403, P =.027) and in the dual task trials (ρ= 0.570, P =.001).

CONCLUSIONS: Older adults contact more obstacles while walking with their attention divided when wearing multifocal glasses. This is likely due to a failure to adopt an appropriate compensatory head movement strategy in pitch resulting in blurred vision due to viewing obstacles through the reading segments of multifocal glasses. Older people, in particular the "oldest old", should avoid wearing multifocal glasses when navigating in challenging and attention demanding environments.

ACKNOWLEDGEMENTS: This study was supported by a National Health and Medical Research Council grant (no. 358055).

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O.77

Sensorimotor correlates of gait variability in older people - A population-based study

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INTRODUCTION: Although intra-individual gait variability is predictive of falls and disability [1, 2], little is understood about the factors that may contribute to gait variability in older adults [3, 4]. Knowledge of the factors contributing to increased gait variability may lead to interventions aimed at reducing falls risk and mobility decline. The aim of this population-based study was to examine whether poor performance on a range of sensorimotor measures was associated with increased gait variability.

METHODS: Individuals aged 60-86 years (n=410) were randomly selected from the Southern

Tasmanian electoral roll. Step length, step time, step width and double support time (DST) were recorded with a GAITRite walkway. Variability for each gait measure was the standard deviation of the measurements recorded during six walks. Standardised sensorimotor measures included visual contrast sensitivity, lower limb proprioception, quadriceps strength, reaction time and body sway on a foam mat (eyes open and closed). Regression analysis was used to determine the relationship between sensorimotor measures and each gait variability measure adjusting for age, height and weight (for all measures) and speed (for spatial measures only).

RESULTS: The average age of the sample was 72 (SD 7.0) years, with 42.9% being female. The average walking speed of the sample was 113.9 cm/sec. Greater sway on a foam mat (eyes closed) was associated with increased variability in all gait measures ($p<0.05$) (Table). Slower reaction time was associated with increased variability in temporal measures ($p<0.05$) and poorer proprioception was associated with increased DST variability ($p=0.01$). Other sensorimotor factors were not independently associated with gait variability measures.

CONCLUSIONS: These results indicate that body sway, reaction time and proprioception are likely factors that may explain gait variability in the general older population. Further research is warranted to determine if inclusion of these factors in intervention programs reduces gait variability, disability and falls risk in older adults.

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	Step length variability (cm)	Step width variability (cm)	Step time variability (ms)	DST Variability (ms)
	β (95 % CI)	β (95 % CI)	β (95 % CI)	β (95 % CI)
Sway ECF (per mm)	0.002 (0.000,0.004)	0.004 (0.002,0.007)	0.031 (0.016, 0.460)	0.024 (0.009,0.038)
Reaction time (per ms)			0.018 (0.004,0.033)	0.025 (0.011,0.039)
Proprioception (per degree)				0.612 (0.136,1.087)

Table 1. Significant multivariable associations between sensorimotor measures and gait variability. β =beta coefficient adjusted for age, height and weight. Step length and step width variability were also adjusted for speed; CI = confidence interval; ECF=eyes closed foam

O.78

The effects of footwear anterior/posterior stiffness on dynamic balance control in older adults

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INTRODUCTION: Recent studies have linked footwear type and falls in older adults [1-3], indicating the importance of the neuromechanical role of footwear in balance control. However, limited footwear studies have investigated the effect of longitudinal bending (anterior posterior (AP) stiffness) on dynamic balance control. The purpose of this study was to determine the effect of AP stiffness on dynamic control of balance in a healthy older adult population during gait perturbations.

METHODS: Sixteen healthy adults (67.8 ± 6.2 yrs, 1.69 ± 0.08 m, 72.1 ± 10.7 kg) were recruited. Participants wore modified footwear with various AP flexion points: posterior, standard, and no flexion point (rigid). The difference in flexion points affects the footwear stiffness. Participants were instructed to walk along a 10m walkway and to terminate gait, with both feet side-by-side, within one stride of hearing the termination signal (audio cue). This was randomly signalled for 33% of the trials (2 of 6) for each condition. Kinematic data was collected using an OptoTrak motion capture system (NDI, Waterloo, Canada) and the center of mass (COM) location was calculated using a 13-segment model. Kinetic data was collected using three force plates (AMTI, Boston, USA), mounted flush with the walkway, during the final three termination foot contacts. The center of pressure (COP) was calculated during each of these contacts and combined as a net COP. Force loading rates (for the first 100 ms of contact) and COM–COP difference (during all stance phases) in the AP direction were calculated.

RESULTS: The maximum AP COM-COP difference (during the of single support phase when termination was signalled) demonstrated a significant difference between each condition. Also during this single stance phase there was a significant difference between the standard and rigid inserts in the minimum AP COM-COP (Table 1). During the initiation of the buzzer there was also a significant difference between the standard insert to the posterior and rigid inserts of the vertical force loading rate.

CONCLUSIONS: The results indicate that the rigid insert may be limiting the ability of an individual to control their COM due an increased vertical loading rate that may be in response to a faster moving COM. This was mimicked by the posterior insert because the flexion point is not directly related to a joint flexion. The larger COM-COP maximum and minimum values also indicate that the posterior and rigid inserts may be imposing a faster COM movement during the single stance heel to toe progression. This increase in progression of the COM while wearing the posterior and rigid inserts could be a hindrance for older adults with respect to dynamic balance control. These results warrant further investigation to determine other possible effects of footwear characteristics on dynamic balance control.

ACKNOWLEDGEMENTS: This study was funded by an operating grant from the Canadian Institutes of Health Research (MOP-77772).

	AP COM-COP		
AP stiffness	Max (m)	Min (m)	Range (m)
Posterior	0.306 [A]	-0.107 [AB]	0.413
Standard	0.316 [B]	-0.093 [A]	0.409
Rigid	0.296 [C]	-0.119 [B]	0.415

Table 1. COM-COP values in AP direction for the three AP stiffness conditions during the single support phase when termination was signalled. Letters represent significant differences between other values in each column

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O.79

Added value of ambulatory activity monitoring in rehabilitation medicine

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INTRODUCTION: As a result of technological developments, measurement of posture and movement outside the movement lab with simple, cheap, user-friendly and portable techniques has made an enormous progress during last years. The department of Rehabilitation Medicine of Erasmus University Medical Center has applied Activity Monitoring and measurement of posture and movement outside the lab in many clinical studies. The presentation will focus on some example studies that show the added value of activity monitoring in medicine.

METHODS: Data on patients with spinal cord injury (SCI), amputation of the leg, neuromuscular disorders, and stroke will be presented. In all studies an Activity Monitor (AM) was applied. The AM is based on multiple body-fixed accelerometers, and aims at prolonged measurement of the amount ("quantity"), way of performance ("quality") and physiological load ("strain") of physical activity, body postures and motions, and upper-limb usage during normal daily life.

RESULTS: Results showed that levels of physical activity can not be reliably assessed by patients themselves or clinicians. Unexpected decreases in levels of physical activity after discharge from the rehab center were found in SCI patients. Significant decreases in physical activity were found in lower leg amputees, but the strain during walking (derived from heart rate) showed not to be different from healthy controls. Chronic Guillain-Barre patients had normal levels of physical activity, despite serious fatigue, decreased fitness and experienced problems in functioning. Chronic stroke patients appeared to compensate with the non-involved hand for the limitations in the involved hand.

CONCLUSIONS: The results show that application of ambulatory techniques provides clinicians data that could not have been obtained by other methods, and that actual movement behavior during normal daily life is different from other aspects of functioning. Future developments will further increase the possibilities and feasibility of ambulatory monitoring.

O.80

Day-to-day variability of physical activity of older persons living in the community

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INTRODUCTION: Time spent on PA decreases with age especially with regards to leisure-time physical activity [1,5]. However, most data were derived from sources such as health surveys and questionnaire-based studies which concentrate on exercise and leisure activities, neglecting domestic activities. Because the suitability of most questionnaires is limited [2], objective tools to measure all aspects of PA including leisure time activities are needed. Until now, pedometers and accelerometers have been predominantly used for long-term monitoring of physical activity of older persons. The purpose of the study was to investigate by intra-individual comparison whether a 24 hour recording period is sufficient to describe PA of one week in 44 older retired persons. Furthermore, we analyzed whether physical performance (PP) can be used as a surrogate marker of PA.

METHODS: PA was captured on seven consecutive days in 44 community-dwelling older adults (80.75 ± 4.05 years) by a body fixed sensor which consists of triaxial accelerometers and single axis gyroscope. PP was measured by the Short Physical Performance Battery (SPPB). It contains unsupported standing, chair rise, and gait speed.

RESULTS: The mean time of walking and the mean "time on feet" of the group was 10.2 hours (± 3.5 hours) and 35.1 hours (± 9.43 hours), respectively, for the duration of seven consecutive days. The intra-individual variability of walking and of „time on feet" of all participants was 31.9% ± 10.79 and 19.4 % ± 8.76, respectively. The accumulated time of variables of PA of all participants showed no differences between weekdays with a variability of 3.8% and 1.8% for walking and „time on feet", respectively. Association between the SPPB and different aspects of PA was limited (walking: r=0.397; „time on feet": r=0.41).

CONCLUSIONS: In this study with older adults we could demonstrate that the measurement of PA of only one day could describe the mean time of activity (i.e. standing and walking) for the whole group, but not for a single person. Therefore, a measurement of a single day cannot be used to compare results for medical interventions in a pre-post design for individual person. Measuring PA of a single day with a motion sensor seems to be an efficient way to obtain comprehensive and objective data on PA on group level. Furthermore, the data presented in this study shows that PP is only a weak surrogate marker of PA. This raises questions on the causal role of other variables such as health status, social status, emotional and cognitive factors and mismatches and matches of the person and their physical and social environment. Future work should be addressed on these aspects. If PP has a small contribution, it is also necessary to question the components of intervention studies to improve PA. Up to now, many intervention studies are focusing on the improvement of PP to increase PA [4]. Maybe other components will have to be addressed to maximize PA, including consideration to the barriers and motivators [3].

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O.81

Activity level and functioning three months after a hip fracture

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INTRODUCTION: Hip fracture patients are characterized by high age, extensive comorbidity and frailty. After hip fracture decline in physical functioning is common and most surviving patients never regain their pre-fracture function. Physical activity (PA) is considered one of the most important factors for prevention of this decline. However, the optimal dosage of PA is not known. One reason for this is lack of objective and feasible methods for assessing PA in the target population. Small lightweight body worn sensors are now available that makes it possible to assess physical activity over days. The aim of this study was to investigate how mean PA measured by body worn sensors during a week correlates with measures of functional balance, fear of falling, cognitive function and activities of daily living (ADL) three months after a hip fracture.

METHODS: A prospective observational study on 35 hip fracture patients (28 women and 7 men, mean age 82.0 ± 5.8 yrs) was performed. Pre-fracture function as well as function three months following hip surgery was assessed. Measures of function included Timed Up-and-Go (TUG), Bergs Balance Scale (BBS) and Falls Efficacy Scale international (FES-I), Mini Mental State Examination (MMSE), and personal and instrumental ADL by the Barthel Index and Nottingham Extended Activities of Daily Living Index (EADL). PA was monitored continuously for one week by a single axis accelerometer fixated to the thigh, and time spent in upright activities (standing and walking) used as outcome variable.

RESULTS: Participants had a mean pre-fracture ADL function of 19.03 (±1.83) out of 20. Functional status three months after surgery is shown in Table 1. Three months after surgery, participants spent 4 hours and 2 minutes (±151.9 minutes) on average in upright activities per day. It was a moderate correlation between PA and BBS (r=0.44), FES-I (r=0.51), MMSE (r=0.55), Barthel Index (r=0.52) and

EADL (r=0.62). Pre-fracture ADL function was found to be important for all functional measures three months after surgery (p<0.01) except for cognitive function (p=0.931). After controlling for pre-fracture ADL function in multiple linear regression models using PA as independent variable, we found significant association between time in upright activities and MMSE (p=0.015) and Nottingham Extended Activities of Daily Living Index (p=0.006).

CONCLUSIONS: PA measured as time in upright position correlated moderately with all measures of function. Pre-fracture ADL function was found to be important for function after the hip fracture. Cognition and EADL were the factors that independently of pre-fracture ADL function significantly affected amount of activity. Further longitudinal studies are needed to study the necessary dosage and intensity of PA and how to organize the rehabilitation in order to improve function after hip fractures.

3 months after surgery			
	N	Mean	SD
Barthel Index (0-20)	34	18.06	2.45
EADL (0-66)	34	36.71	17.62
TUG (sec)	32	20.49	8.22
BBS (0-56)	34	39.97	13.87
FES-I (16-64)	29	30.69	10.62
MMSE (0-30)	34	25.82	4.29
PA (min)	35	242.20	151.94

Table 1 Results from the 3 months examination.

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O.82

Quantification of physical activity and behaviour change: developing a novel method for analysing objective measures of physical activity

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INTRODUCTION: Physical activity is an important physiological signal that reflects human behaviour and functional ability. Modern body-worn sensors (e.g. accelerometers) allow for detailed objective long term monitoring. Analysis currently focuses on quantifying amount and intensity of physical activity. However, individual may maintain the same total amount or intensity of activity (sedentary or walking events) but may behave differently and perform the activity in different ways accumulating a total amount in smaller or larger bouts. This difference in behaviour is reflected in the distribution of activity events. We have developed a generic methodology to quantify the distribution of physical activity events using robust statistical parameters based on power law statistics. This method enables physical behaviour to be quantified. We tested the validity of this method to identify the distribution of physical activity events and to distinguish between different groups of subjects.

METHODS: We compared participants recruited from 5 distinct groups: (1) healthy postal worker (Ha, N=53) with an active occupation (mail delivery), (2) healthy postal workers (Hs, N=54) with sedentary office based work, (3) subjects with chronic fatigue syndrome (CFS, N=14), (4) people with chronic low back pain (LBP, N=4), people with Parkinson disease (PD N=18). Each subject wore an activPAL monitor continuously for 3-7 days, which recorded their activity profile as a sequence of three possible activities (sedentary, upright or walking) [1]. The distribution of the length of these events was analysed to develop quantitative markers of physical activity and behaviour

RESULTS: Analysis showed that sedentary, upright and walking events have a complex distribution which follows a power law relationship [2]. Whilst the total time spent in each activity (sedentary, upright, walking) does not distinguish between groups the power law relationship is significantly different between the groups (p<0.01). Using Lorentz curves, derived from the distribution of events, the GINI index *G* can be calculated to quantify the pattern of accumulation of time spent in each activity. *G* is significantly different between groups (p <0.01). For sedentary activities $G_{PD} > G_{LBP} > G_{CFS} > G_{Hs} > G_{Ha}$ which means that the Parkinson disease group tend to accumulate sedentary time predominantly in long bouts while healthy active individual use shorter period of sedentary time.

CONCLUSIONS: The pattern of accumulation of sedentary, upright and ambulatory events follows a power law distribution. This distribution can be parametrised using robust statistics. This method of analyzing physical activity events demonstrates the potential to provide a sensitive means to describe patterns of activity and has the potential to quantify changes in behaviour. Using this technique it might be possible to better evaluate the impact of disease, occupation and rehabilitation.

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O.83

Development of a clinical balance evaluation systems test (BESTest) for differentiating balance deficits

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INTRODUCTION: Current clinical balance assessment tools treat balance as a single control system and rarely include dynamic balance in a variety of functional conditions. The goal of this study was to develop and test a clinical balance assessment tool that differentiates involvement of a variety of balance control systems under dynamic conditions.

METHODS: The 'BESTest' consists of 36 items, grouped into 6 systems: Biomechanical Constraints, Stability Limits, Anticipatory-Transitions, Postural Responses, Sensory Orientation and Dynamic Gait. In two inter-rater trials, 21 subjects with and without balance disorders, ranging in age from 50 to 88 were rated concurrently on the BESTest by 19 therapists, students, and balance researchers. Concurrent validity was measured by correlation between the BESTest and balance confidence, measured with the Activities of Balance Confidence (ABC) Scale. A 'Mini-BESTest for Dynamic Balance' was then developed using analysis factor and Rasch analysis to optimize the psychometric properties of the test, based on testing 88 patients with balance deficits (aged 60.7 years ± 17) with diagnoses including Parkinson's disease, vestibular disorders, cerebellar ataxia, stroke, neuropathy, multiple sclerosis, and orthopedic disorders.

RESULTS: Consistent with our theoretical framework, patients with different diagnoses scored poorly on different sections of the BESTest. The intraclass correlation coefficient (ICC), measuring the inter-rater reliability for the test as a whole, was 0.91, with the 6 section ICCs ranging from 0.79 to 0.96. The Kendall's coefficient of concordance among raters ranged from 0.46 to 1.0 for the 36 individual items. Concurrent validity of the BESTest with the ABC Scale was $r = 0.636$; $p < .01$. After removing correlated and nondiscriminatory items, the mini-BESTest was reduced to 14 items with a 3-, instead of a 4-level, ordinal scale that took 12 minutes to administer. The variance explained by the estimated Rasch measures was 82%, and the distribution map of subject ability and item difficulty showed a fairly even spread with a normal distribution. The reliability indices of the miniBESTest were: item separation index = 5.21 and item separation reliability = 0.96; person separation index = 2.29 and person separation reliability = 0.84.

CONCLUSIONS: The BESTest is unique in allowing clinicians to determine the type of balance problem to direct specific treatments. The miniBESTest quickly provides a novel clinical assessment of dynamic balance with excellent psychometric properties.

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O.84

Effect of a physiotherapy treatment on sagittal plane gait biomechanics of knee osteoarthritis patients: preliminary results.

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INTRODUCTION: Dynamic mechanical factors can be involved in the progression of knee osteoarthritis (OA). It is now well recognized that patients with knee OA present modification in their gait biomechanics that can contribute to improper joint loading [1]. According to recent clinical guideline recommendations, lower limb strengthening exercises are key components of non-invasive knee OA management [2]. However, the effect of these treatments on gait biomechanics needs further investigation. This study presents the preliminary results of physiotherapy treatment effects on gait biomechanics of patients with knee OA. Results relating to sagittal plane kinematics and kinetics during the loading period of the gait cycle are presented.

METHODS: Kinematic and kinetic parameters were collected during gait of 29 participants diagnosed with knee OA before and after they received 12 weeks of physiotherapy treatment. Knee kinematics was recorded using a 3D knee exoskeleton mounted with reflexive markers. The position of the markers was recorded with an optoelectronic motion analysis system (Vicon 460, Oxford metrics). Kinetic data were measured by Kistler force plates embedded in a treadmill (ADAL, Medical Development, France). Femoral and tibial linear accelerations were recorded using two triaxial accelerometers

(Physilog, BioAGM, CH), fixed on the exoskeleton. The gait of 15 asymptomatic participants was evaluated in order to obtain reference data. The physiotherapy treatment included isometric quadriceps and hamstring strengthening exercises and it was administered twice a week. Paired t-tests were performed to assess the treatment's effect on quadriceps and hamstring strength and on angular displacement and joint moment at every 1% of the loading period of the stance phase of gait. Maximal femoral and tibial anterior posterior (AP) linear accelerations during this period were also extracted and compared between pre and post treatment evaluations. Linear accelerations were used as an indicator of AP joint stability.

RESULTS: Increased quadriceps and hamstring strength was observed after treatment (quads: 24.4 ± 9.66 kg pre-tx vs. 30.91 ± 10.82 kg post-tx; hamstring 17.86 ± 4.31 kg pre-tx vs. 19.58 ± 4.89 kg post-tx). No difference was found for angular displacement in the sagittal plane. As regards knee moments, a significant increase ($p<0.05$) in external knee flexion moment was detected from 3% to 24% of the gait cycle after treatment. Decreased in AP linear accelerations was also found after the treatment (-88 g ± 0.42 pre-tx vs. -0.74 g ± 0.38 post-tx, p=0.02).

CONCLUSIONS: The effect of a physiotherapy treatment based on strengthening exercises on gait biomechanics of knee OA participants was investigated. The results show that the gain in isometric quadriceps and hamstring strength may contribute to increased AP knee stability, as demonstrated by lower acceleration values post treatment. With greater knee stability, the OA participants may be more confident to use their quadriceps during the loading period. These results partly support the high level of evidence associated with strengthening exercises in the management of knee OA patients.

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O.85

Approach for rehabilitation treatment of cerebellar patients presenting with postural ataxia

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INTRODUCTION: Recently, physiotherapists have reported short-lasting symptomatic improvements in cerebellar patients after a training program consisting of standing on a moving platform. The aim of this study was to develop a rehabilitation program for patients with cerebellar-based postural ataxia.

METHODS: In our program patients presenting with cerebellar disorders (CBL) and healthy subjects (CTRL) were tested. They stood on a dynamic platform to which different types of variable sinusoidal stimulation movements, either sidewards or frontwards-backwards, were applied (passive movements). After a three-minute stimulation period subjects had to perform actively a block of 20 fast or precise sidesteps, starting from an feet-apart-position to a feet-together-position (Fig 1,1) and back (Fig 1,2). These steps were used for quantification of any improvement. The sequence of stimulation movements and sidesteps was repeated eight times. During these manouvers the centre of vertical pressure (CVP) was recorded.

RESULTS: Precise sidesteps were clearly more difficult than fast sidesteps for both CTRL and CBL. There was a clear distinction in the time course between fast and precise steps in CTRL. This difference however, was frequently less pronounced, or even absent, in CBL. The variation of the CVP trajectory during the stand phase and during the step phase (Fig. 1) was clearly smaller in CTRL, although some CBL showed a reduction of the variation, i.e. improvement at the end of the whole session. This encouraging result was further supported by written reports of the CBL who were asked to score their condition subjectively in the week following our test program.

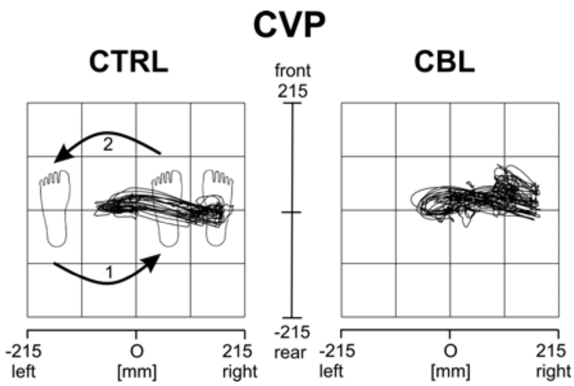

Fig.1 Trajectories of the CVP (statokinesigrams) during sidesteps of a CTRL and CBL

CONCLUSIONS: These preliminary results give reason to hope that simple physical treatment may temporarily reduce postural-based ataxia in CBL.

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O.86

Intensive coordinative training improves motor performance in degenerative cerebellar disease

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INTRODUCTION: The cerebellum is known to play a strong functional role in both motor control and motor learning. However it is an open question for instance whether cerebellar patients have lost the ability of practice-dependent motor learning or whether they require longer-duration or higher-intensity training to learn. Hence, the benefit of physiotherapeutic training remains controversial for patients with progressive cerebellar degeneration. Only very few clinical studies have evaluated physiotherapeutic interventions for patients with cerebellar ataxia, showing moderate improvements of ataxia symptoms based predominantly on patient-specific training programs.

METHODS: In an intra-individual case-control design we examined the effectiveness of a four-week intensive coordinative training for 16 patients suffering from progressive ataxia due to cerebellar degeneration (n=10) or degeneration of afferent pathways (n=6). Effects were assessed by clinical rating scales for ataxia (ICARS,SARA), a clinical balance score, an individual goal attainment score evaluating personally relevant activities of daily living and by quantitative movement analysis of gait as well as of a static and a dynamic balance tasks. In the dynamic balance task, subjects stood in an upright position with both legs on a treadmill. The task was to compensate for the perturbation given by the treadmill, which was programmed to run for one second. Subjects were instructed to compensate the perturbation by anteriorly directed steps. Evaluation was conducted immediately prior to and after training, and 8 weeks before and after training. As control, we compared patients' performance on consecutive assessments, both with and without intervening training.

RESULTS: Significant improvements in motor performance and reduction of ataxia symptoms were observed in all clinical scores after training and were sustained at follow-up assessment. Patients with predominant cerebellar ataxia revealed more distinct improvement than patients with afferent ataxia in several aspects of gait: velocity, step length, lateral sway and intra-limb coordination improved significantly after training and persisted at follow-up. Consistently, in patients with cerebellar but not with afferent ataxia, the regulation of balance in static and dynamic balance tasks was significantly improved after training. The necessity of continuous training became obvious in the dynamic balance task on the treadmill. For the cerebellar group, body sway was significantly reduced in the comparison of pre/post-intervention ($p=0.01$), but also significantly increased in the follow-up assessment ($p=0.03$). This finding indicates that the improvements gained by the intensive coordinative training could not be preserved fully for this very demanding task of reactive balance control. This phenomenon is most likely explained by the patients' limited training of demanding whole body coordination at home after the intervention period for security reasons.

CONCLUSIONS: Despite progressive cerebellar neurodegeneration, patients' motor performance significantly improved, enabling them to achieve personally meaningful goals in everyday life. Training effects were more distinct for patients without affection of afferent pathways. For both groups, continuous training seems crucial for stabilizing improvements and should become standard of care.

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O.87

Balance training with visual feedback can improve balance abilities in people with spinal cord injury

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INTRODUCTION: Despite the vast majority of studies utilizing balance training (BT) in individuals with neurological disorders [1-3], there is a lack of knowledge of how BT with visual feedback can improve the balance abilities of people with spinal cord injury (SCI). As such, the present study was performed to examine the effect of BT with visual feedback in subjects with SCI.

METHODS: Five participants with chronic motor and sensory incomplete SCI (ASIA C, spinal lesions ranging from C1 to T12) completed the BT three days per week for a total of twelve sessions. Individuals with incomplete SCI were allowed to participate if they were able to stand for at least 5 minutes without any form of assistive device and to walk 10 m or more with the help of parallel sidebars. During the BT, participants stood on a force platform and were instructed to shift their centre of pressure (COP) presented as a cursor on a monitor screen in indicated directions. Various games were used to target different aspects of balance function, namely steadiness, symmetry, and dynamic stability. To assess the effect of the BT after the training period, the Romberg test, an evaluation of the limits of stability (LOS), and a locomotor test on the treadmill were used.

RESULTS: During the course of the BT, a significant improvement in performance was revealed in all five subjects and all training exercises. Figure 1 exemplifies the performance on the second and twelfth day of the training during a COP task that required the subject to track a visual target moving clockwise around the centre of the screen. The improvement in the voluntary balance abilities was accompanied by a significant enlargement of the LOS after the BT (Fig. 2). In addition, the mean area of the COP fluctuation during standing decreased to 62±28% (eyes open) and 63±23% (eyes closed) after the training, indicating an increase of the average level of steadiness following the BT. Finally, the BT resulted in a significant enhancement of locomotor function in three of five subjects as revealed by an increase in stride length and a prolonged duration of the single stance phase (up to 150% of pre-training value).

CONCLUSIONS: The results of this study suggest that BT with visual feedback has a potential to improve balance control in SCI patients during both standing and walking. It can be assumed that the observed balance improvements may have been caused by an optimization of postural synergies and a sensory re-weighting during and after the BT. Thus, retraining balance function in individuals with SCI using visual feedback could become a promising tool that may complement existing rehabilitation methods.

ACKNOWLEDGEMENTS: The Japan Society for the Promotion of Science.

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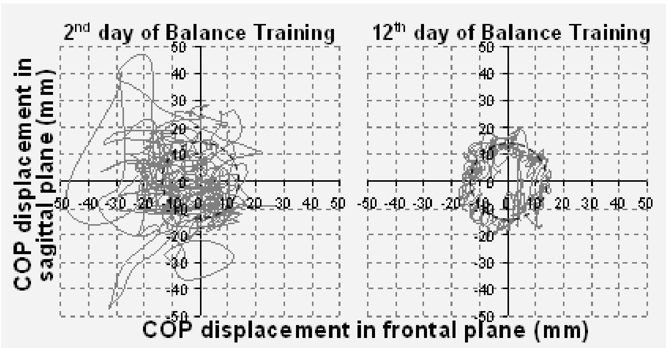

Fig 1. COP during the target tracking exercise

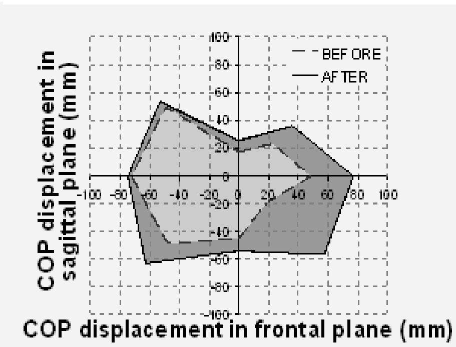

Fig 2. Test of limits of stability

O.88

Circuit-based rehabilitation improves gait endurance but not usual walking activity in chronic stroke: a randomised clinical trial

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INTRODUCTION: Task oriented gait training, including walking in all directions, over different surfaces, obstacles, inclines and steps, consistently results in improved clinical measures of gait, particularly self selected gait speed and endurance. There is also evidence for gains in strength when progressive resistance principles are applied. However, it is not known whether these improvements translate into greater walking function in an individual's usual environments. The aim of this study was to determine if circuit-based rehabilitation would increase the amount and rate of walking that an individual with stroke carries out in their usual environment.

METHODS: Fifty-eight participants (mean age 69.1 ± SD 12.9 years) at least six months following stroke were randomised to either exercise or control groups. The exercise group had 12 sessions of clinic-based rehabilitation delivered in a circuit class, consisting of strength and functional training relevant for walking. The control group received a comparable duration of group social and educational classes. Usual walking performance was monitored over a three day period using the StepWatch Activity Monitor outputs (mean steps/day, percentage of time with no steps, peak activity index and highest stepping rate in one minute). Clinical tests were gait speed (10 metre walk test) and endurance (Six minute walk test), confidence (Activities-Based Confidence Scale), self reported mobility (Rivermead Mobility Index) and self-reported physical activity (Physical Activity and Disability Scale). Outcome assessment was performed at baseline, immediately following the intervention and 3 months following the intervention by an independent physiotherapist blinded to treatment assignment.

RESULTS: Participants had a mean gait speed of 0.70 ± 0.29 m/s. Twenty-six (45%) used an assistive device. Intention-to-treat analysis revealed that in the exercise group gait endurance ($p<0.05$) and balance related confidence ($p<0.05$) improved immediately following the intervention, but these gains were not retained at three months. No changes in the amount of usual walking performance (mean steps/day and percentage of time with no steps) or rate (peak activity index and highest stepping rate one minute) were observed. The control group showed no changes in any of the outcome measures immediately following the intervention, but exhibited improved confidence ($p<0.05$) at three months post-intervention.

CONCLUSIONS: Circuit-based rehabilitation leads to early, but not sustained improvements in gait endurance and confidence but does not change the amount or rate of walking performance in usual environments. Future studies should consider whether rehabilitation needs to occur in usual environments in order to improve walking performance.

O.89

Advances in vestibular rehabilitation: high-tech vs. low-tech optokinetic stimulation and the role of supervision

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INTRODUCTION: Customized vestibular rehabilitation incorporating optokinetic stimuli via whole-body or visual environment rotators is more beneficial than the former in isolation for improving dizziness, postural instability, and particularly visual vertigo in patients with a chronic peripheral vestibular disorder [1]. The equipment used though is expensive and the twice weekly therapy sessions are not standard practice where patients often do their exercises unsupervised. The purpose of this study is to do a controlled between-group comparison of patients' responses to a customized exercise regime incorporating exposure to optokinetic stimuli via a full field visual environment rotator (Group A) or on a DVD with (Group B) and without supervision (Group C).

METHODS: Sixty patients with chronic peripheral vestibular disorder who have previously undergone conventional vestibular rehabilitation without notable improvement are randomly allocated into Group A, B or C. Group A and B attend once weekly therapy sessions for eight weeks and are also provided with a customized home exercise program. Group C are given a customized home exercise program and the DVD to do unsupervised for eight weeks. Treatment response is assessed at baseline and eight weeks with dynamic posturography, Functional Gait Assessment (FGA), and subjective questionnaires for symptoms, symptom triggers, and emotional state.

RESULTS: Fifty-five percent of Group C patients do not complete the trial compared to 5% for Group A and 0% for Group B. Two-way ANOVA analysis on preliminary data for 39 patients (mean age 49.7, range 28-73) shows significant improvements for all outcome measures ($p<0.01$) but no significant differences between groups. Statistical analysis on within-group data shows significant improvements for all groups for global vertigo, visual vertigo, and autonomic symptom scores, although Group A and B show greater improvements ($p\leq0.01$). Posturography and FGA scores significantly improve only for Groups A and B ($p\leq0.01$). Anxiety scores significantly improved only for Group B ($p<0.05$) and depression only for Group A ($p<0.05$); no change was noted for Group C.

CONCLUSIONS: The DVD is an effective and economical method of incorporating optokinetic stimuli into vestibular rehabilitation programs. However rehabilitation must be supervised for greater compliance and improvements, particularly for balance, gait and emotional state.

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O.90

Visual vertigo and vestibulopathy: I. Balance functions and posturography findings

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INTRODUCTION: Visual vertigo (VV) is frequently associated with vestibulopathy. VV patients experience dizziness due to exposure to dynamic ocular inputs[1-3]. Although their subjective complaint of dizziness due to visual stimulation by the environment is very pronounced, the influence of VV on their balance and anxiety level is not well defined or understood. The main goals of this study were to assess whether the presence of absence of VV in vestibulopathic subjects will impact on their abilities to maintain balance.

METHODS: Ten people with vestibulopathy and VV, 11 with only vestibulopathy but no VV, and 10 age-matched healthy controls participated in the study. We investigated postural sway with computerized dynamic posturography (CDP) under 6 different visual and surface conditions in the sensory organization test (SOT) and with two standing clinical tests and functioning test, i.e., Romberg stance on foam, tandem stance on floor, and the timed repeated sit-to-stand (x5) test. The clinical standing measurements were done under regular eyes-open or eyes-closed conditions or with exposure to dynamic visual inputs. All subjects completed questionnaires specific to VV and to anxiety level using the Short Anxiety Screening Test (SAST) [4]. One-way ANOVA was applied, with subject group (3 levels) as the between-subject factor. Posthoc comparisons with Bonferroni adjustment were applied where significant main or interaction effects exist (P<0.05).

RESULTS: The VV group was significantly different from the vestibular and healthy control groups in the first four of the six conditions of the SOT test (P<0.05). As for condition#5 (eyes-closed, sway referenced) significant difference was found only between the VV group and healthy controls (p=0.004), although a trend of increased postural sway still existed in the vestibular group. On the other hand, no difference was found between the VV group and the healthy control group in the two clinical standing position tests. However, a significant difference was found between the VV group (11.6±4.4 sec) as compared to the healthy control group (8±1.7 sec, P=0.04) in the functional test (sit-to-stand with eyes open) with or without exposure to dynamic visual inputs. The anxiety level was significantly higher in the VV group compared to both the vestibulopathic and healthy control groups (24.1± 5.7 vs 15.7 ± 1.6 vs 13.5± 2.8, respectively; P=0.0001).

CONCLUSIONS: The ability to maintain balance with an underlying vestibulopathy is decreased in the presence of visual vertigo. Even a common daily task such as sit-to-stand can be impaired in VV subjects when subjected to an environment of visual stimulation. Thus, older adults suffering from VV may carry a high risk for falls. It is not surprising that VV patients have a higher level of anxiety as compared to other patients with vestibular deficits or healthy controls. In vestibular rehabilitation, when VV is present, it is thus recommended that controlled visual stimulation should be considered in performing balance and functional activities.

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O.91

The relationship between positional vertigo and visual dependency.

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INTRODUCTION: It is not known if the increased visual dependence present in some patients with chronic vestibular symptoms is a life-long trait or whether it is secondary to the vestibular vertiginous symptoms. The underlying question is whether visual dependence is a neural plastic phenomenon that can be modified by vestibular excitation or dysfunction. In order to address this question we measured visual dependence, before and after Hallpike positional manoeuvre (and repositioning procedures if appropriate), in patients with active BPPV and in two control groups.

METHODS: We studied 20 BPPV patients with a positive Hallpike plus repositioning treatment (mean age 60 years ± 14 years SD), 20 patients with symptoms suggestive of BPPV but in whom the Hallpike manoeuvre was negative (mean age 53 years ± 14 years SD) and 20 age-matched normal control subjects (mean age 55 years ± 12 years SD). The tests [1] included the rod-and-frame test and the rod-and-disc test (both seated) which measure the degree of tilt of a visual vertical line, induced by a static frame tilt or a roll motion rotating disc, respectively. In addition we measured the amount of body sway path induced by the roll motion disc (subjects standing). All recordings in all groups were obtained twice, before and immediately after the positional (and repositioning in the BPPV group) manoeuvre.

RESULTS: The normal subjects swayed significantly less than the patients, while watching the rotating disc. There was a wide range of frame- and disc-induced visual vertical tilt in all groups. All groups showed a positive correlation between disc-dependency and age; frame-dependency also increased with age in the patient groups. In paired sample t-tests, the normal subjects showed a significant decrease in disc-induced body sway and frame-induced visual tilt, on repeat testing (ie after the positional manoeuvre). However, the only significant change in either of the patient groups was a reduced disc-induced visual tilt for the positive BPPV subjects.

CONCLUSIONS: Subjects with vestibular symptoms are more unstable than normal subjects when presented with disorienting visual stimuli and are less able to improve their stability with repeated exposure. These findings suggest that long term vestibular dysfunction does increase postural visual dependency and that it also interferes with postural adaptation to disorienting visual stimuli (in this case adaptation to the rotating disc). Regarding the original question that prompted this study, we failed to induce a significant increase in visual dependence by means of a single BPPV attack, so longer periods of vestibular stimulation may be required to modify visual dependence.

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O.92

Classification of idiopathic bilateral vestibulopathy and relations of the subtypes to stabilometric findings

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INTRODUCTION: Idiopathic bilateral vestibulopathy (IBV) is a clinical entity representing bilateral dysfunction of the peripheral vestibular system due to unknown causes. For the diagnosis of IBV, it is required to prove bilateral decreased function of the peripheral vestibular system. Clinically, decreased peripheral vestibular function has been shown using caloric tests or rotation tests. While these tests provide information of the functions of the lateral semicircular canal and the superior vestibular nerve, they do not do information concerning the otolith organs. Vestibular evoked myogenic potential (VEMP) is a kind of evoked electromyography. VEMP has been recorded on the sternocleidomastoid muscle (SCM) as responses to relatively intense sound stimulation. VEMP is regarded as a sacculo-collic reflex and applied as a clinical test of the saccule and the inferior vestibular nerve. Using VEMP testing in addition to caloric testing, we tried to classify patients with IBV and studied the relation of subtypes to their stabilometric performance.

METHODS: Patients diagnosed as having IBV were enrolled in this study. Diagnostic criteria of IBV were as follow. 1. Bilaterally decreased peripheral vestibular function shown by decreased caloric responses and/or decreased VEMP amplitudes. 2. No associated hearing loss. 3. Exclusion of bilateral vestibular dysfunction by known causes such as meningitis, aminoglycoside ototoxicity and so on. 4. Exclusion of familial cases. Patients with bilaterally decreased (or absent) caloric responses but normal VEMP were classified as the superior vestibular nerve type (superior IBV) while patients with bilaterally decreased (or absent) VEMP amplitudes but normal caloric responses were as the inferior vestibular nerve IBV type (inferior IBV). Other patients were classified as the mixed type (mixed IBV). All the enrolled patients also underwent the stabilometric tests with eyes open and closed. Romberg ratios were calculated as the ratio of the value with the eyes closed to the value with the eye open.

RESULTS: The mixed IBV showed large Romberg ratios. When we compared Romberg ratios of patients with superior IBV with those of patients with inferior IBV, patients of the superior IBV showed the tendency of poorer stabilometric performance than those of the inferior IBV.

CONCLUSIONS: These results suggested the vestibular end-organs innervated by the superior vestibular nerve might have more contribution for the good stabilometric performance than those innervated by the inferior vestibular nerve.

O.93

Gait phase instability in cases with small acoustic neuroma – analysis by the use of tactile sensor -

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INTRODUCTION: The most frequent symptom of acoustic neuroma is a cochlear symptom, despite of its origin mostly from vestibular nerve. Vestibulospinal abnormality such as gait instability may be observed only in cases with large tumor, and small tumor cases usually show seemingly normal gait. How about when gait is analyzed in detail? The present study shows that even in small tumor cases gait instability could be caused, especially under gait with eyes closed.

METHODS: Twenty two cases with fresh small acoustic neuroma cases of less than one cm from the porus acoustics were enrolled for the present study. Their average age was 55.2±7.0 years old. Age matched control was set by nine normal volunteer with an average age of 52.3±4.5 years old. Foot pressure sensor (F-scan system) has been used for the analysis of gait. Using this pressure-sensing system, gait characteristics were translated into digital signals and computer-aided analysis was performed. Subjects were asked to walk straight with eyes open or closed at a distance of eight meters, keeping the most comfortable pace (free gait). As for gait related variables, coefficient of variation (CV) of stance, swing, and double support (DS) were employed for assessment of gait stability. In addition, area ratio and average length of trajectories of center of force (TCOF) were also measured and compared.

RESULTS: None of the patient showed gait abnormality with eyes open. However, under gait with eyes closed, AT patient had significantly greater instability in gait phase related variables such as stance, swing and double supports. No significant change was obtained in area ratio and mean length of TCOF. When compared with those patients who had decreased caloric response, they had greater CV values than those who had not. Thus it has been shown that even a small acoustic tumor could cause gait instability with some different contribution between superior and inferior vestibular nerve system.

CONCLUSIONS: Small acoustic neuroma does cause gait instability under gait without visual cue. Superior vestibular nerve system could contribute more than that of inferior vestibular nerve system for gait phase stability.

O.94

Trunk postural control in subjects with low-back pain or a recent history of low-back pain

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INTRODUCTION: Low-back pain has been associated with poor postural control as indicated by an increase in postural sway or earlier loss of balance in challenging postural tasks [1,2]. The direction of causality in this association is unclear. On one hand, it might be a result of LBP, for example due to loss of proprioceptive acuity [3]. On the other hand, poor postural control might be a causative factor, as poor control might predispose to injury [4]. If poor postural control plays a causative role either in the incidence or in the recurrence of LBP, control should be impaired in individuals that have recovered from LBP.

METHODS: 331 of the participants of a longitudinal study on lifestyle and health volunteered to perform a seated balancing task [5]. Based on a questionnaire, subjects were subdivided in three groups: current-LBP, recent-LBP (no current pain, but pain within last 12 months), no-LBP (no LBP in last 12 months). Dynamic trunk postural control was investigated using a seat mounted over a hemisphere with a radius of 39 cm. After practice, 3 trials of 30 s were performed with 30 s rest between trials. RMS amplitudes, mean power frequency (MPF), short-term diffusion coefficients (DS) and critical point (CP) coordinates of sway in anterior-posterior (x) and left-right (y) directions were calculated.

RESULTS: The no-LBP, recent-LBP and current-LBP groups consisted of 164, 79 and 58 subjects, respectively. No differences were found between these groups for potential confounders. RMSx and RMSy were significantly different between groups, with smaller values in the recent-LBP than in the no-LBP group, while the current-LBP group was not different from the no-LBP group. MPF values were lowest in the current-LBP group, with MPFx significantly lower than in the no-LBP group and MPFy significantly lower than in the recent-LBP group. DSx and DSy were highest in the no-LBP group, with significant differences between this group and the recent-LBP group only. CP values were generally lower for the recent-LBP group than both other groups.

CONCLUSIONS: In contrast with previous findings [1], postural sway amplitudes in an unstable sitting task were not different between subjects with current LBP than in controls, while subjects with a recent history of LBP had smaller sway amplitudes. Frequency of postural sway was lower in subjects with current LBP than in subjects with a recent history of LBP and subjects without LBP. Trunk postural control of subjects without LBP was more stochastic as reflected by higher short-term diffusion coefficients. We submit that these findings can be explained by the disturbing effect of current pain on postural control and by differences in effort invested in the task between subjects with LBP and a recent history of LBP on one hand and controls on the other hand.

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O.95

Outcome evaluation of ankle osteoarthritis treatments using spatio-temporal gait parameters and plantar pressure during unconstraint long distance walking

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INTRODUCTION: Ankle arthrodesis (AD) and ankle arthroplasty (AP) are two typical surgical treatments for ankle osteoarthritis (AO) [1]. Despite the clinical interest, there is a lack of their outcome evaluation using objective criteria. Gait analysis [2] and plantar pressure assessment [3] are appropriate techniques to detect pathologies in orthopaedics, though they are mostly used in lab with few gait cycles. In this study, we propose an ambulatory device based on inertial and plantar pressure sensors to compare the gait during long-distance trials between healthy subjects (H) and patients with AO or treated by AD and AP.

METHODS: Four groups of subjects were involved in the study: 11 patients with AO, 9 patients treated by AP, 7 patients treated by AD and 6 control subjects. An ambulatory measurement system (Physilog®, CH) with two gyroscopes fixed on shanks was used for gait analysis while the plantar pressure of pathologic foot was measured using a portable pressure insole (Pedar®-X, DE). The subjects were asked to walk 50 meters in hospital corridor in two trials. Mean value (μ) and coefficient of variation (CV%) of spatio-temporal gait parameters were calculated for each trial [4]. Pressure distribution was analyzed in ten sub-regions of foot according to [3] and several pressure metrics were estimated for each gait cycle and averaged over each trial. All parameters were compared among the four groups using multi-level model-based statistical analysis.

RESULTS: Table 1 compares some parameters between the four groups. Significant difference ($p<0.05$) with control was noticed for AO patients in maximum force in Medial Hindfoot (MH), Medial Forfoot (MF) and Central Forefoot (CF), while these differences were no longer significant in all regions in AP and AD groups. Cadence, speed but not stride length of all pathologic groups showed significant difference with control. Both treatments showed a significant improvement in double support and stance. AP decreased variability in speed, stride length and knee ROM.

CONCLUSIONS: In spite of a small sample size, this study showed that ankle function after AO treatments can be evaluated objectively based on plantar pressure and spatio-temporal gait parameters measured during unconstraint walking outside the lab. First our results showed objectively disease related changes for AO. Second, they provided positive outcomes of both treatments, particularly AP. Third; same changes were observed for AD and AP. In conclusion, the combination of these two ambulatory techniques provides a promising way to evaluate foot function in clinics.

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	Cadence (step/min)		Double Support (%)		Stance (%)		Speed (m/sec)		Stride Length (m)		Knee ROM (deg)		Maximum force (Body Weight %) Sub-regions		
	μ	cv	μ	cv	μ	cv	μ	cv	μ	cv	μ	cv	MH	MF	CF
H	59.1± 1.9	2.1± 0.4	20.3± 1.3	10.6± 1.2	60.1± 0.7	1.8± 0.2	1.2± 0.0	2.6± 0.5	1.2± 0.0	2.1± 0.4	55.0± 1.8	2.4± 0.3	44.4± 2.4	40.3± 2.4	27.1± 2.0
AO	**50.6± 2.3***	2.7± 0.5	**25.4± 1.7***	10.3± 1.4	**62.7± 0.8***	2.1± 0.2	**1.0± 0.1***	**4.0± 0.7***	1.2± 0.0	**3.1± 0.4***	53.5± 2.3	**3.6± 0.3***	**33.1± 4.0***	**30.5± 3.2***	**19.9± 3.3***
AP	**53.2± 2.4***	2.4± 0.5	23.7± 1.8	8.0± 1.4	61.8± 0.9	1.5± 0.2	**1.1± 0.1***	3.5± 0.7	1.2± 0.1	2.6± 0.5	51.6± 2.4	2.9± 0.4	37.0± 4.3	**32.6± 3.3***	21.4± 3.4
AD	**52.3± 2.5***	2.6± 0.4	22.5± 1.9	10.5± 1.7	61.3± 1.0	1.9± 0.3	**1.0± 0.1***	**4.0± 0.6***	1.2± 0.1	**3.0± 0.4***	**49.5± 2.5***	**3.1± 0.4***	39.5± 4.7	**28.0± 3.6***	**15.2± 3.8***

Table 1 Gait parameters and maximum force in foot regions expressed as mean±std. (*): Significant difference between control and pathologic groups.

O.96

Relationship between physical function and stiffened pattern of movement during gait in patients with knee osteoarthritis

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INTRODUCTION: Persons with knee osteoarthritis (KOA) have decreased knee range of motion and increased co-contraction (CC) of lower limb muscles during gait. While this stiffened pattern of gait has been well described in this population, its relationship to the patients' physical function (PF) has not been determined. This study examined if patients with KOA who walk with a more stiffened pattern of gait have worse PF scores.

METHODS: Subjects with KOA over the age of 50 participated (n=123). Clinical criteria were used to designate a Most and Least-Affected (MA and LA) leg. PF was measured by the time to perform the Get Up and Go (GUG) test and by the WOMAC self-report measure. Lower extremity joint kinematics and surface electromyography were measured during level walking. The excursion of the hip, knee and ankle was calculated during the loading phase of stance (heelstrike to 1st peak of the vertical ground reaction force curve). Mean CC of selected muscle pairs was computed during the loading phase from: Quadriceps Medial and Lateral (QM and QL), Hamstring Medial and Lateral (HM and HL), Tibialis Anterior (TA), and Gastrocnemius Medial and Lateral (GM and GL). Pearson product-moment correlation coefficients (r) were calculated to determine the relationship between joint excursion and CC variables with PF scores for MA and LA legs. Paired-t tests were used to examine side to side differences.

RESULTS: Knee and hip excursion were inversely related (MA r = -0.49 and LA r = -0.66) showing that when there is a lack of knee motion there is an increase in hip excursion in both MA and LA legs. As a result, decreased knee excursion and increased hip excursion was associated with slower GUG times (Table 1). In addition, greater hip motion was related to worse WOMAC scores. This trend of less knee motion and greater hip motion being associated with worse PF was also seen within subjects, as the MA leg had less knee and more hip excursion than the LA leg ($p < 0.01$). Higher mean CC was related to slower GUG times on both LA and MA legs and worse WOMAC scores in 5 out of the 7 MA muscle couples (Table 1).

CONCLUSIONS: These data suggest that during the loading phase of stance, people with KOA who have worse PF adopt an altered pattern of movement by increasing CC of lower limb muscles, stiffening their knees and increasing hip motion. This pattern of movement may be an attempt to avoid symptoms such as pain and/or instability at the knee, and the increased hip motion may be a compensatory mechanism to absorb some of the load that could not be absorbed at the knee joint. Further investigation is needed to determine if physical therapy intervention can target this pattern of movement and therefore improve overall PF in people with KOA.

ACKNOWLEDGEMENTS: This research was supported by NIH grant R01 AR048760.

		LA leg		MA leg	
		GUG	WOMAC	GUG	WOMAC
Joint Excursion	Hip	.45‡	.22*	.33‡	.19*
	Knee	-.45‡	-.05	-.29‡	-.11
Mean CC	QL:HM	.41‡	.25‡	.42‡	.20*
	TA:GM	.27‡	.05	.30‡	.23‡
	QL:HL	.26‡	.18	.14	.17
	QM:HM	.37‡	.17	.30‡	.25*
	QL:GL	.39‡	.23*	.30‡	.23*
	QM:GM	.26*	.02	.22*	.22*
	TA:GL	.20*	.04	.28‡	.17

Table 1 Correlations of joint excursion and CC variables with PF scores (n=123). *p<.05; ‡p<.01

O.97

Kinematics of the three components of a novel ligament-compatible total ankle prosthesis: in-vivo fluoroscopic analysis at three consecutive follow-ups.

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INTRODUCTION: A novel Total Ankle Replacement (TAR) design allows complete congruence at its three components throughout plantar-/dorsi- flexion (PlDo) arc because of compatibility of the articulating surfaces with the retained ligaments [1]. Accurate measurements of 3D motion of prosthetic components in in-vivo tests can be performed by stereo-fluoroscopic analysis [2]. This was used in patients operated with this TAR to assess quantitatively whether this mechanics occurs after operation, and whether it is maintained at consecutive follow-ups (FU).

METHODS: Three patients with osteoarthritic ankle were implanted with the novel TAR (BOX, Finsbury Orthopaedics, Leatherhead-Surrey, UK). This is a ligament-compatible convex-tibia fully-congruent three-component prosthesis, with metal tibial and talar components and a mobile bearing polyethylene insert instrumented with 3 tantalum beads in known positions. At 12, 18 and 24 month follow-up, patients were analyzed during stair ascending/descending, PlDo against gravity, and in static double leg stance using a standard fluoroscope (CAT Medical System, Rome, IT) at max 10 Hz. Tibial and talar component reference frames were defined onto the relevant CAD models; the insert reference frame was defined by using the 3D coordinates of the tantalum beads. Position and orientation of the 3 components were obtained by an iterative 2D-to-3D matching procedure with a 0.5 mm/1.0° accuracy [2]. PlDo, inversion-eversion (InEv), internal-external (InEx) rotation, as well as antero-posterior (AP) translation of the talar and meniscal components with respect to the tibia were expressed according to a standard convention for joint rotations and here reported.

RESULTS: In PlDo against gravity, all kinematics variables were significantly coupled to PlDo ($p<0.05$). This was also true for AP translations in all other motor tasks ($p<0.01$). In stair ascending, PlDo range increased significantly between 1st and 2nd follow-up ($p<0.05$) and between 2nd and 3rd ($p<0.01$). Mean overall ranges are in the Table below.

CONCLUSIONS: The study shows that motion of all TAR components, including the polyethylene insert, can be tracked in-vivo by this procedure. The AP translation of both the insert and talar components and their correlation to PlDo support further the features claimed for this novel TAR, implying also the full congruence between the three components. This mechanism would result in a better restoration of ligament natural function. In the future, a larger cohort of patients together with gait analysis will provide more synergic information. In addition to the tibial and talar components, this study for the first time reports also 3D motion of the insert tracked directly.

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	AGAINST GRAVITY			**STAIR ASCENDING**			**STAIR DESCENDING**		
	1FU	***2FU***	***3FU***	***1FU***	***2FU***	***3FU***	***1FU***	***2FU***	***3FU***
PlDo [°]	11.4±3.4	11.9±3.1	10.7±3.0	3.9±2.5	4.0±1.2	6.7±1.5	7.2±2.6	9.3±3.7	4.6±2.6
InEv [°]	2.8±1.7	3.0±1.6	3.5±1.8	2.6±0.6	2.3±0.3	2.9±1.4	3.3±1.3	5.6±0.9	2.7±0.2
InEx [°]	2.4±1.1	2.5±1.5	2.8±2.8	2.6±0.2	2.9±0.8	3.5±1.9	2.7±1.0	2.1±1.3	3.5±1.2
AP meniscal [mm]	2.4±0.4	2.4±0.6	2.5±0.6	2.0±0.6	2.1±0.1	2.4±1.0	2.7±1.0	2.5±0.3	1.9±0.6
AP talar [mm]	3.6±0.9	3.2±0.7	2.2±0.6	2.0±1.5	1.7±0.6	1.6±0.4	2.4±0.6	2.2±1.6	1.9±0.4

Poster Session Tracks

Poster Session #1 – Monday June 22 & Tuesday June 23 — **ROOM**

P.1 – P.24	Animal studies, basic human neurophysiology and functional imaging Sensory, motor and integrative control mechanisms	[Podestà]
P.26 - P.48	Higher level control, adaptation, and age-dependent effects Cognitive, attentional, and emotional influences	[Podestà]
P.49 - P.65	Higher level control, adaptation, and age-dependent effects Adaptability, compensation, substitution, plasticity	[Podestà]
P.68 - P.75	Higher level control, adaptation, and age-dependent effects Development	[Podestà]
P.76 - P.87	Clinics and interventions Pathology and pathophysiology: Parkinson's disease and basal ganglia disorders	[Podestà]
P.88 - P.97	Clinics and interventions Pathology and pathophysiology: Ataxia	[Podestà]
P.98 - P.113	Clinics and interventions Pathology and Pathophysiology: Orthopaedic disorders	[Podestà]
P.114 - P.120	Clinics and interventions Pathology and pathophysiology: Stroke, Cerebral Palsy, spasticity	[Room 38]
P.121 - P.137	Clinics and interventions Prevention: Falls	[Room 38]
P.138 - P.139	Clinics and interventions Treatment: Local and systemic pharmacological interventions	[Room 37]
P.141 – P.182	Methodological approaches, technologies and applications Biomechanics	[Room 37-36-Capitano]
P.183 - P.191	Methodological approaches, technologies and applications Sport & Exercise	[Capitano]

Poster Session #2 – Wednesday June 24 & Thursday June 25

P.193 – P.217	Animal studies, basic human neurophysiology and functional imaging Sensory, motor and integrative control mechanisms	[Podestà]
P.218 – P.223	Higher level control, adaptation, and age-dependent effects Pathology and Pathophysiology: Cognitive impairment	[Podestà]
P.224 – P.236	Higher level control, adaptation, and age-dependent effects Ageing	[Podestà]
P.237 – P.264	Animal studies, basic human neurophysiology and functional imaging Sensory, motor and integrative control mechanisms: Multisegmental and interlimb coupling	[Podestà]
P.265 – P.273	Clinics and interventions Pathology and pathophysiology: Stroke, Cerebral Palsy, spasticity	[Podestà]
P.274 – P.297	Clinics and interventions Pathology and pathophysiology: Parkinson's disease and basal ganglia disorders	[Podestà]
P.298 – P.318	Clinics and interventions Pathology and pathophysiology: Stroke, Cerebral Palsy, spasticity	[Podestà-Room 38]
P.319 – P.327	Clinics and interventions Pathology and pathophysiology: Visual and vestibular impairment	[Room 38]
P.328 – P.346	Clinics and interventions Habilitaton & Rehabilitation: Sensory training, cueing, biofeedback	[Room 37-36]
P.347 – P.378	Methodological approaches, technologies and applications Advanced assessment tools and protocols	[Room 36-Capitano]
P.380 – P.384	Clinics and interventions Treatment: Prosthetics and orthotics	[Capitano]

P.1

Effects of visual information on muscle adjustments during voluntary body sway

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INTRODUCTION: Studies of multi-muscle postural adjustments are important for understanding changes with age and postural disorders in neurological patients. The purpose of this study was to investigate the adjustments of leg muscles during voluntary body sway in different visual conditions. We hypothesized that muscle activation patterns differ across tasks while applying an internally generated postural perturbation. In particular, we tested a hypothesis that visual feedback practice could lead to form stronger coordinations for stabilizing the location of the center of pressure (COP).

METHODS: Healthy subjects stood on the force platform (the F-Scan system was on the top of force platform) and performed whole body cyclic rotation about the ankle joint at 1 Hz in three different visual conditions: eyes open, eyes closed and visual feedback. Electromyographic activity of leg muscles and ground reaction forces were recorded. 12 consecutive cycles for each of three experimental conditions were used for data analysis. Each cycle was time normalized as 100%. COP_{AP} coordinate was averaged and rectified EMG signals were integrated over 1% time windows of the cycles. In addition, two control variables that representing reciprocal and co-activation commands were calculated based on the normalized EMG integrals at different joint and muscle group levels.

RESULTS: Changes in the visual conditions led to significant differences in the magnitude of muscle activation patterns. The reciprocal variable increased significantly with visual feedback. This was associated with multi-muscle adjustments for stabilizations of COP shifts and body segments.

CONCLUSIONS: The results suggest that visual feedback practice could lead to form stronger coordinations stabilizing COP trajectories. It may benefit for training of persons with impaired postural control such as elderly persons and persons in the course of rehabilitation after an injury.

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P.2

Change in the transmission within several spinal pathways in cerebral palsy patients

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INTRODUCTION: Efficacy of transmission in many spinal pathways has been widely investigated in resting state in patients with central nervous system lesions, including postsynaptic pathways (reciprocal Ia inhibition, propriospinally-mediated group I/II excitation) and presynaptic mechanisms (presynaptic inhibition of Ia terminals, postactivation depression). Most of these investigations were made in patients with adulthood cerebral lesions, i.e. in stroke patients, in whom abnormalities of the efficacy of the transmission within most these pathways were extensively reported. In contrast, data related to the efficacy of spinal pathways in patients with perinatal cerebral lesions, i.e. cerebral palsy (CP) are lacking. We designed this study to compare the efficacy of transmission within pre- and postsynaptic spinal pathways in healthy volunteers, CP patients and results reported in the literature in stroke patients.

METHODS: Four spinal pathways were investigated at rest in CP patients and compared to healthy volunteers: reciprocal inhibition, propriospinally-mediated group I/II excitation, presynaptic inhibition of Ia terminals, postactivation depression. Monosynaptic test reflexes were evoked in the soleus and in the quadriceps (Q) muscles. Presynaptic inhibition and reciprocal inhibition were evoked by stimulating antagonistic group I fibres. Postactivation depression was investigated by changing the frequency of the stimulus rate from 0.16Hz to 1Hz. Peroneal-induced excitation of Q motoneurones was used to test propriospinally-mediated group I/II excitation.

RESULTS: In CP patients, compared to healthy volunteers, we found that (i) postactivation depression was decreased, (ii) presynaptic inhibition was strongly depressed, (iii) propriospinally-mediated group II excitation was significantly increased, and (iv) reciprocal inhibition was unchanged. When compared to stroke patients, the results showed that postactivation depression is less depressed in CP patients whereas presynaptic depression is more decreased. Only propriospinally-mediated group II excitation was increased in CP patients, whereas group I and group II excitation was enhanced in stroke patients. Reciprocal inhibition was not modified in CP patients, whereas the inhibition was decreased or replaced by facilitation in stroke patients.

CONCLUSION: Although cortical lesions are present both in stroke and CP patients, pathophysiological changes in spinal pathways differ in the two populations. These differences suggest that the central nervous system reorganisation following lesions is likely different when cerebral lesion occurred in perinatal period in an immature brain or in a mature brain. Another explanation could be that the areas of the cerebral damage are different.

P.3

Foot position tends to be sensed as more medial than the actual foot position

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INTRODUCTION: Present study was conducted to determine the features of errors between the actual foot positions and the sensed foot positions when no visual feedback around the feet was provided. In studies regarding the importance of vision during walking, several researchers have discussed that the risk of perturbation during walking increases if there is no visual feedback around the feet [e.g. 1]. In addition, those studies provide clear evidence that increased failure was due to inappropriate limb control. Moreover, many studies report that proprioception, especially sensed joint angles are not quite accurate when there is no visual feedback provided [e.g. 2]. Therefore, the sensed foot position may be affected by errors of sensed joint angles in each joint of the lower extremities when there are no on-line visual feedbacks allowed, and these errors may cause inappropriate foot placement when no visual feedback of foot position are provided. However, differences between the actual foot positions and the sensed foot positions have not been clarified.

METHODS: 10 young participants were asked to place different parts of their foot as close as possible to a target line without stepping onto it, while wearing modified goggles that obscured their view of their feet. Once they felt that their foot was appropriately placed, the distance between their foot and the target line was measured.

RESULTS: The results revealed that participants tended to step 20-30mm over the target line when asked to place the most lateral part of their foot near the target line (Trials Lat.), and tended to place their foot 20-30mm away from the target line when asked to place the most medial part of their foot near the target line (Trials Med.). Moreover, there was a significantly larger VE for when asked to place the most anterior part (Trials Ant.) or posterior (Trials Post.) part of their foot near the target line compared to the Trials Lat. and Trials Med. However, there were no statistical differences between AE among the placed foot parts, which indicates that the total amount of errors were similar among the trials. Furthermore, there were no significant effects regarding feet dominancy and their interactions between conditions (fig. 1).

CONCLUSIONS: In the present study, we sought to clarify characteristics of sensed foot position without visual feedback of the foot. Using an LDG-based apparatus to scan the edge of the placed feet, we conclude the following: 1) the sensed foot position tended to shift more medial than the actual foot position, and 2) the sensed foot position in the A/P direction varies more than that in the M/L direction.

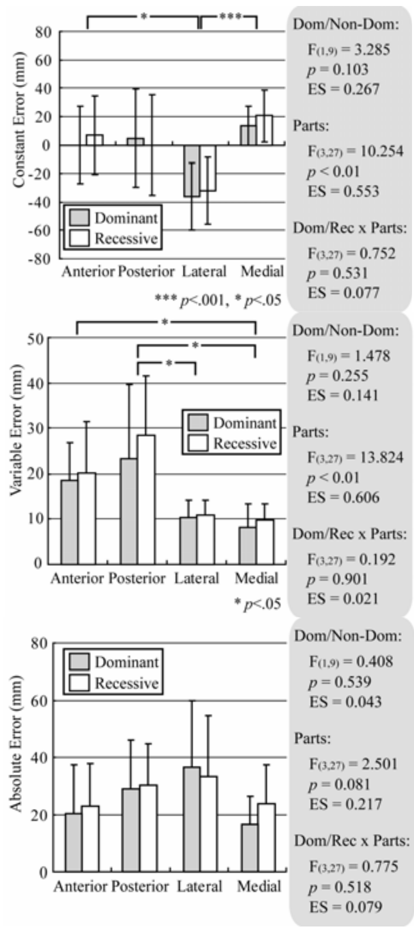

Fig. 1 Mean CE, VE, AE scores among the trials. Negative CE value represents the foot placed on the target line, whereas a positive CE value represents the foot placed away from the line

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P.4

Importance of binocular vision in controlling foot-reach and placement parameters during a locomotion task

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INTRODUCTION: Research comparing reaching and grasping performance under various binocular and monocular viewing conditions has shown that monocular vision provides sufficient information to plan and execute the initial reach but binocular vision is important to providing precise on-line control of the terminal reach and grasping phases. In the present study, we investigate the importance of binocular vision to the control of lower-limbs during a locomotor task.

METHODS: Starting from stationary, participants (n=8) were required to place alternate feet onto floor-based targets spaced to facilitate 'normal' gait. The initial target (target 1) was located on a platform that could be moved in the ML direction (at 50mm/s). Repeated trials when target 1 was stationary, or moved laterally at instant of lead-limb toe-off or mid-swing were undertaken under binocular and monocular viewing conditions. Using a target that unexpectedly moved highlighted aspects of on-line control, whilst the relatively low shift-velocity ensured dynamic balance would not be compromised. Foot-reach kinematics, on-line corrections and foot placement parameters were assessed (Optotrak) for the step onto target 1.

RESULTS: There was no difference in foot-reach kinematics (peak velocity, time to peak velocity) between vision conditions (p>0.05). However, swing duration was longer under monocular (643±0.11ms) compared to binocular viewing conditions (622±0.10ms, p=0.039), mostly due to a longer foot-placement period (from reach-velocity reversal point up to foot contact (monoc, 190±0.06ms; binoc, 178±0.05ms, p=0.043)). Trajectory adjustment latency (in response to target shift) was shorter (p=0.038) and the foot tended to have a higher velocity compared to target for a longer period under monocular viewing (p=0.056), although there was no difference across vision conditions in the ML foot-target distance (mean, SD) during swing. Foot placement accuracy and precision were significantly worse when stepping onto the moving target (compared to stationary), but values were similar across vision conditions. The one exception to this was when the target shifted at mid-swing, when absolute ML foot placement accuracy was reduced for monocular compared to binocular viewing (p=0.017, Figure 1).

CONCLUSIONS: Results indicate that monocular vision was sufficient to plan initial foot-reach but binocular vision was important in providing precise control of final foot placement. These findings are in general agreement with those found for reaching and grasping, which suggest the same visual pathways/mechanisms are involved in the control of both upper and lower limbs. The reduced foot trajectory adjustment latency for monocular viewing trials suggest that target-movement information acquired binocularly requires more processing time.

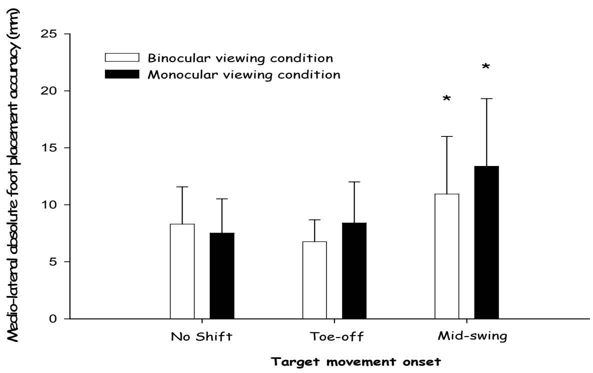

Fig.1 Absolute ML foot placement accuracy under monocular and binocular viewing conditions

P.5

Can peripheral vision guide perturbation-evoked reach-to-grasp balance-recovery reactions?

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INTRODUCTION: Reach-to-grasp reactions are a prevalent and functionally important response to loss of balance. To prevent falls, these reactions must be initiated and executed very rapidly. Some recent results suggest that the CNS may deal with these temporal constraints by using peripheral vision (PV) to guide the hand motion, thereby eliminating delays associated with use of saccades to identify and localize a suitable handhold. However, studies of voluntary reaching have shown accuracy to be reduced when guided by PV. Within the context of balance-recovery reactions, such effects could have serious consequences (i.e. falls) if the result is a failure to grasp a handhold effectively. This study investigated how the CNS resolves speed-accuracy trade-offs when forced to use PV to guide perturbation-evoked reach-to-grasp reactions.

METHODS: Reach-to-grasp reactions were evoked via sudden unpredictable forward and backward platform translation, in 12 healthy young adults (22-29yrs). Prior to each perturbation, a handhold (diameter=32mm; grip length=125% of hand width) located to the front and right of the subject was moved unpredictably back and forth along a transverse axis. The handhold was controlled to move to, and stop at, several different dwell positions before stopping at one of three final positions, corresponding to visual angles of 20°, 30° and 40° (relative to straight-ahead gaze). The perturbation was then delivered after a random delay (1-3s). Subjects were required to guide the reach-to-grasp reaction using either central vision (fixated directly on the handhold) or PV (fixated on a computer screen directly in front of them), and performed a concurrent visuo-cognitive task in half of the PV trials.

RESULTS: Although there appeared to be some trends toward reduced reach accuracy in PV trials, there was no significant effect on ability to achieve a functional grasp. There was also no effect on deltoid latency or peak wrist velocity; however, reliance on PV did significantly increase movement time, with larger effects at more eccentric handhold locations (eg 75ms increase at 40°). The duration of the wrist deceleration phase also increased (by 30ms) in PV trials. The only effect of the addition of the cognitive task was a slight (15ms) increase in movement time.

CONCLUSIONS: The results indicate that PV can guide rapid perturbation-evoked reach-to-grasp reactions with a level of accuracy sufficient to achieve a functional grasp, even when the handhold is relatively small and its location is varied unpredictably prior to perturbation onset. However, PV-guided movements were slowed substantially when the handhold was located in the more extreme periphery. Such slowing could potentially increase risk of falling in some situations. Surprisingly, performing a concurrent visuo-cognitive task had relatively little impact. Ongoing work is examining the ability of older adults to use PV to guide these reactions.

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P.6

A visual illusion leads to safer stepping behaviour: Action follows perception

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INTRODUCTION: Tripping is a common factor in falls and a typical safety strategy to avoid tripping on steps and stairs is to increase foot clearance over the step edge. In the present study we asked whether the perceived height of a step can be increased using a visual illusion and whether this leads to the adoption of a safer stepping strategy, in terms of greater foot clearance over the step edge. The study also addresses the controversial question of whether motor actions are dissociated from visual perception.

METHODS: A perceptual illusion was produced by superimposing visual patterns onto a block (152mm high) in one of two configurations. These patterns introduce a version of the horizontal-vertical illusion [1] in which vertically-oriented lines appear longer than horizontal. In 21 subjects (28.2 ± 8 yr) with normal vision, perceived step height was assessed (sliding scale) with subjects standing 2 walking paces from the block. Subjects then walked up and onto the block. Lead-limb maximum toe elevation was assessed (Vicon Mx motion analysis system) during repeated (n=5) trials (each configuration) under binocular and monocular viewing conditions.

RESULTS: Subjects perceived the step to be higher in the V configuration compared to the H configuration (p=0.01), increasing on average by 5.3mm (~4.5% of average perceived height, Fig 1a). There was no difference in the estimation of the height of the step between binocular and monocular vision conditions (p=0.35). Subjects increased maximum toe elevation in the V configuration compared to the H configuration (Figure 1b, p<0.001) and toe elevation was greater for both configurations under monocular conditions (p=0.003), but there was no significant interaction (p=0.49). Linear regression analyses showed highly significant associations (p<0.02) between perceived step height and maximum toe elevation for all conditions.

CONCLUSION: The perceived height of a step can be manipulated using a simple visual illusion, leading to the adoption of a safer stepping strategy in terms of greater foot clearance over a step edge. This could have functional value in making the most dangerous steps, the first and last ones that most people trip over when ascending stairs [2] appear taller and generate a higher clearance, and such an application deserves further study. In addition, the strong link found between perception of a visual illusion and visuomotor action provides additional support to the view that the original, controversial proposal by [3] of two separate and distinct visual streams for perception and visuomotor action should be re-evaluated.

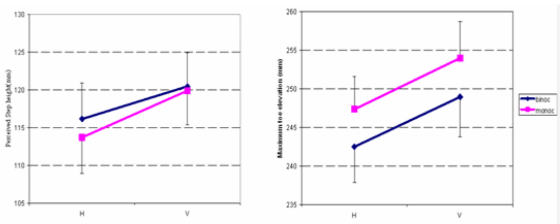

Fig. 1 a) Mean (± SE) perceived step height (mm) and b) Mean (± SE) maximum lead toe elevation (mm), for H and V target configurations and monocular and binocular vision conditions

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P.7

A quantitative analysis of neuronal interactions between eye position and optic flow representation in superior parietal cortex of macaque monkey

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INTRODUCTION: When we move in the environment the visual perception of self-motion is mainly provided by optic flow, expanding fields if we move forward, contracting if we move backwards. The focus of expansion (FOE) of such flow field is an important cue for heading perception. However, during locomotion, the eyes do not always fixate towards the direction of motion, and these extraretinal signals can change the FOE position with respect to the fovea. The specific aim of this work was to determine whether neurons in the macaque's parietal area PEc can integrate signals related to optic flow selectivity with those about eye position, to assess area PEc role in the neural network responsible to create a stable visuo-spatial representation for guiding locomotion. Previous results showed that PEc neurons can integrate optic flow and eye position signals. Here, we further investigated their relationship using a new quantitative method to compare the neuronal responses to same retinal FOE offset with different eye position.

METHODS: Single neuron activity (n=53 cells) were recorded in two monkeys trained to look at a fixation point (FP) on a computer monitor, during the presentation of radial expanding/contracting optic flow stimuli. We tested all the combination of FP and FOE in nine locations in a 3x3 grid at 15° distance each. To reduce the number of independent variables, we transformed the FOE coordinates in a single angle coding (i.e. (X15,Y0)→0°, (X15,Y15)→45°), while the eye position angles where flipped by 180° to compare the same FOE retinal position with different eye position. We then performed a linear regression based on orthogonal least squares. The goodness of fit was computed as the sum of the squared distances between the data and the model. This analysis was carried out for both stimuli (expansion and contraction).

RESULTS: Results showed that 22 neurons follow similar trend in the activity during the expansion phase (slope m>0), while 17 neurons have opposite trend (m<0). During contraction, 26 neurons have m>0 and 20 m<0. For the remaining neurons, the model could not fit the data with a sufficient precision. Fig. 1 shows the histogram of the slope coefficient m in the expansion phase, fig. 2a-b shows a particular case in which m<0 with a good fit of the model.

CONCLUSIONS: Comparing the neuronal activity to the same retinal position of the FOE but different eye position, we found two different subpopulations of neurons: 48 respond similarly to FOE independently from eye position, while 37 are modulated by the combination of FOE and eye positions. These results agree with previous studies supporting the hypothesis that area PEc neurons can encode FOE position in eye-centered coordinates, but in presence of eye rotation this area integrates this information with eye position, providing a new coding in head-centered coordinates.

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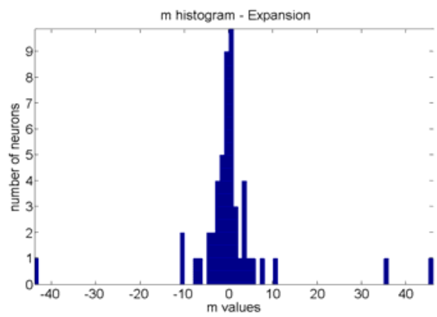

Fig. 1

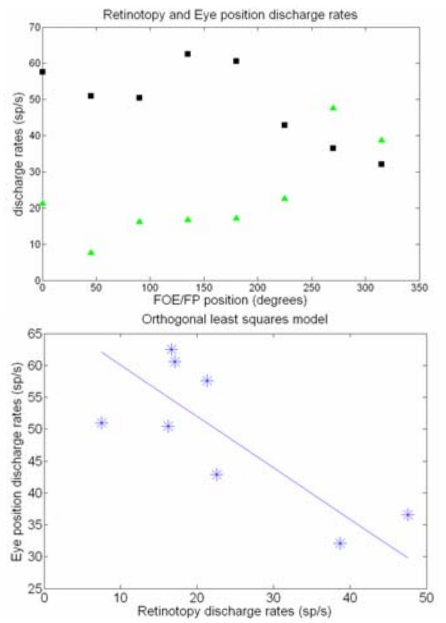

Fig. 2a-b

P.8

Correlations between tongue position and postural control

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INTRODUCTION: The discovery of five different kinds of esteroceptors in the point in which the naso-palatine nerve appears on palate [1] addressed different researches to the study of tongue posture and movement. In fact this anatomical point, known as "palatine spot", is the place in which tongue tip lays during rest and from which starts during swallowing. Moreover Martin et al [2] documented a higher activation of cerebral cortex during tongue elevation than during swallowing, with a significantly higher activity in cingulate gyrus, supplementary motor area, precentral and postcentral gyrus, premotor cortex, putamen and thalamus. On these bases different authors underlined a relation between tongue dysfunctions and postural unbalance, but with no experimental verification. The aim of this study is to evaluate the influence of tongue position on body posture and balance control using stabilometric and baropodometric tests.

METHODS: A total of 180 subjects with disfunctional swallowing (mean age 18.15 years, SD 3.32 years) were divided in a control group (160 subjects) with normal frenulum and in a short frenulum group (20 subjects). All subjects underwent stabilometric and baropodometric tests under two conditions: with tongue in normal position and with tongue tip on palatine spot. All trials were conducted with eyes closed. Confidence Ellipse Area (CEA) and Sway Path Length (SPL) stabilometric parameters, and Heel Load (HL) and Feet Load Difference (FLD) baropodometric, parameters were analyzed thought repeated measures ANOVA and Tukey-Kramer multiple-comparison test.

RESULTS: CEA showed significant differences between groups ($p=0.010$) and within condition ($p<0.001$); with significant increase for both groups in palatine spot condition and with higher values in control group. SPL showed significant differences between groups ($p=0.020$) and within conditions ($p<0.001$) and a significant interaction of group and condition factors ($p=0.001$); with significant differences between group only in normal condition and significant increase within conditions only in control group. In palatine spot condition, HL showed significant increase for boot feet ($p<0.001$) and FDL a significant decrease ($p=0.001$) no significant differences between groups or interaction of group and condition were detected in baropodometric parameters (Fig.1).

CONCLUSIONS: The results suggest a correlation between tongue position and posture. The worsening of stabilometric outcomes could be interpreted as the effort in dysfunctional subject to reach palatine receptors; this effort is particularly evident in subjects with anatomical impediment such as short frenulum. Moreover, the improvement in subjects' posture, recorded by baropodometry, could be the signal of neuro-muscular effect of palatine receptors on posture.

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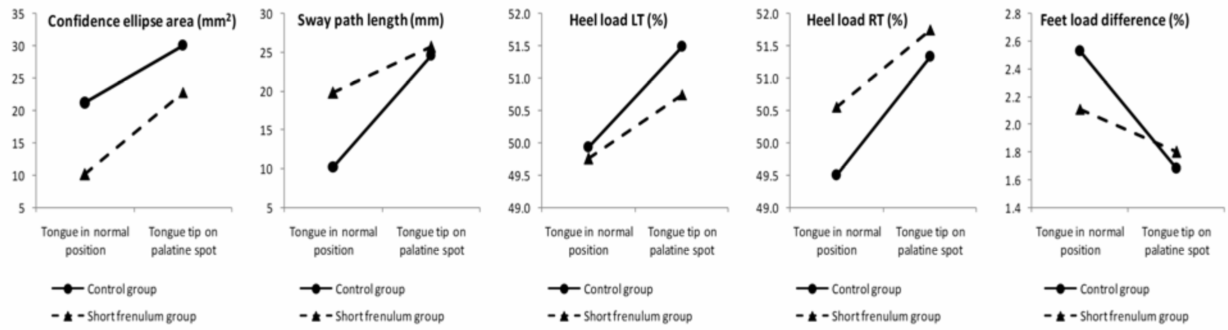

Fig.1 Mean results for stabilometric and baropodometric parameters

P.9

Multimodal representation of visual perception for guiding locomotion in area PEc of macaque monkey

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INTRODUCTION: The visual perception of self-motion is mainly provided by optic flow (OF) and the position of the focus of expansion (FOE) is a critical cue for heading perception. However, in everyday life, the gaze is not always directed to the FOE, given that eye/head movements change the FOE position with respect to the fovea. Macaque's Ventral Intraparietal (VIP) area is known to integrate OF and eye movement signals [1], enforcing some sort of coordinate transformation in heading perception. We are concerned with area PEc, an architectonic field of the superior parietal cortex so named by Pandya & Seltzer [2], whose neurons are involved in visual motion and OF processing, besides encoding the early stage of reaching arm movements and responding to proprioceptive stimulation. All these functional features make area PEc a good candidate for signal integration. The specific aim of this research was to determine whether PEc neurons are able to integrate signals related to optic flow selectivity with those about eye position. This would be relevant to assess if optic flow is coded in eye- or head-centered coordinates in this area and which could be the role of these representations in the neural network responsible to create a stable visuo-spatial frame for guiding locomotion.

METHODS: We recorded single unit activity (n=111) in two monkeys (*M. fascicularis*) trained to look at a fixation point (FP) on a computer monitor, during the presentation of radial expanding/contracting optic flow stimuli. To elucidate if eye position modifies the optic flow selectivity and which is the exact relationship between FOE and eye position, we varied the spatial position of FOE and FP. We initially tested the retinotopic organization of FOE neuronal selectivity, presenting FP in the center of the screen and FOE in one of nine locations in a 3x3 grid at 15° distance one from each other. Then we tested the eye position effect on the FOE retinotopic organization, presenting FOE in the center of the screen and FP in one of the eight peripheral locations. We compared the responses to optic flow at same retinal FOE offset and different eye position. We also tested the effect of eye position on non-retinotopic representation of optic flow, presenting FOE and FP concentric in each of the nine locations.

RESULTS: We found that 74% of neurons had an interaction effect between optic flow type (expansion or contraction) and FOE position in space. Furthermore, 66% of cells showed an interaction effect between optic flow type and eye position in space. This modulation was either a gaze dependent facilitation or an inhibition of the visual response to optic flow. Most of these neurons (83%) did not show any gaze field without visual stimulation.

CONCLUSIONS: These results support the hypothesis that area PEc neurons can encode the FOE position in eye-centered coordinates, but in presence of eye rotations the FOE position information is integrated with that of the eye position providing a new coding in head-centered coordinates. This may be relevant for visuo-motor coordination during body movements, such as walking or vehicle driving.

ACKNOWLEDGEMENTS: Supported by MURST and Fondazione Carisbo - Bologna.

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P.10

The supraspinal locomotion network in progressive supranuclear palsy: brain metabolism during actual locomotion in FDG-PET

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INTRODUCTION: The objective of the study was the characterization of pathological changes in the supraspinal network of locomotion in patients with progressive supranuclear palsy (PSP) during actual locomotion.

METHODS: 12 PSP patients and 16 age- and sex-matched healthy controls were included in the study. As a locomotion paradigm persons had to walk with a medium velocity in a basement floor providing uniform visual environment for 10 minutes. Then [^{18}F]-Fluoro-desoxyglucose ([^{18}F]-FDG, max. 200MBq) was injected intravenously while the subject continued walking for further 10 minutes. Imaging started 30 minutes after tracer injection. In all participants a second [^{18}F]-FDG scan was done under resting conditions (in lying position with eyes open). For analysis the [^{18}F]-FDG-PET images were normalized to individual T1 weighted high-resolution MRIs to account for atrophy effects. Imaging data at locomotion and rest were compared separately for both groups by a paired t-test ($p<0.005$, uncorrected values). Mean images of the locomotion and rest condition were statistically compared between the

PSP and control group using an unpaired t-test ($p<0.005$, uncorrected values).

RESULTS: Comparison of glucose metabolism in PSP patients and controls, for both groups similarly showed strong increases in glucose uptake in the vermal cerebellum, the parahippocampal and the precentral gyrus during locomotion compared to rest. Comparing the locomotion condition in both groups, a higher glucose uptake was found in PSP patients bilaterally in the postcentral gyrus, the primary visual cortex V1, the motion-sensitive visual area V5, the superior temporal and inferior parietal gyri (parieto-insular vestibular cortex). Relative reduced glucose uptake in PSP patients during locomotion was seen in the anterior cingulate gyrus and the pontomesencephalic tegmentum (pedunculopontine nuclei). The same deactivations were present, when comparing the resting condition in PSP patients versus controls.

CONCLUSIONS: In the present study it could be shown, that PSP patients show increased metabolism in multisensory cortical areas (visual, vestibular, somatosensory) during locomotion, possibly to compensate for postural instability. The postural and gait problems in PSP patients may result from disruption of supraspinal neuronal locomotion circuits at the mesencephalic level by degenerative changes in locomotor regions end their connections (e.g. midbrain locomotion center = pedunclopontine nucleus, pathways to vermal cerebellum).

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P.11

Gait during continuous walking: Impact of friction, surface condition, and perception

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INTRODUCTION: In this study, we investigated the effects of friction and perception on gait adjustment during continuous walking on different floors and surface conditions. The following questions were examined: Do floor materials and contaminant conditions affect an individual's gait? If so, what strategy will an individual adopt while continuing to walk on these various floors and conditions? What is the relationship among the proprioceptive feedback received by participants, the available coefficient of friction (ACOF) of the floors, and corresponding gait adjustments?

METHODS: A straight-path walkway was specially designed to allow five different floor materials to be quickly changed for randomized presentation. For each floor material, three surface conditions (dry, water, and glycerol) were tested. Participants wore a safety harness and were asked, for each testing condition, to walk on the walkway from end to end repeatedly and as quickly as possible without slipping. A PIAST slipmeter was used to measure the ACOF of the floors. After completing each test condition, participants rated the perceived slipperiness of the floor they had just walked on. Normalized normal force and utilized coefficient of friction (UCOF) at the heel strike landing phase were calculated from the ground reaction force (GRF) data collected using forceplates embedded under the walkway. Data of 30 participants were analyzed and the Linear Mixed Model was used for statistical analyses.

RESULTS: Results indicated that the floor materials and contaminant conditions had significant effects on peak normalized normal forces ($p<0.001$) as well as peak UCOF values ($p<0.001$). The values of peak normalized normal forces and UCOF during the heel strike phase were found to be lower when individuals walked on lower friction floor surfaces. However, the analysis also indicated the ACOF was not the only factor that affected an individual's gait. Differences in the proprioceptive feedback received while participants continued walking on the floor surfaces also influenced changes in gait which were reflected in the GRF as well as UCOF profiles. In fact, the perceived slipperiness ratings (based on proprioceptive feedback) seemed to provide a better correlation with UCOF than friction measurements. Fig. 1 shows the relationship among participants' slipperiness ratings (i.e., proprioceptive feedback), the measured ACOF of the floors, and corresponding gait adjustments reflected by the peak UCOF value.

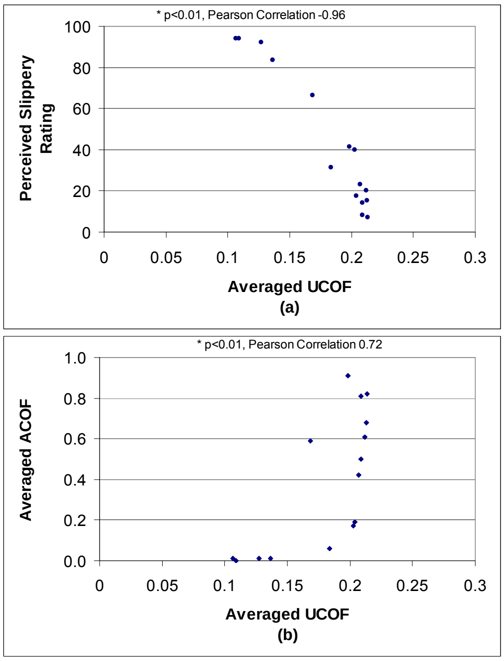

Fig.1 (a) Correlation of averaged perceived slipperiness ratings with averaged UCOF and (b) the correlation of averaged ACOF with averaged UCOF among various floors and surface conditions

CONCLUSIONS: Participants alter their gait to accommodate changes in various walking surface conditions. Both the ACOF and proprioceptive feedback during walking play important roles in the control of an individual's movements and affect how individuals adapt their gait in order to walk safely under various environmental conditions.

P.12

Imaging supraspinal locomotor control in humans

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INTRODUCTION: Locomotion in humans and other vertebrates is based on spinal pattern generators, which are regulated by supraspinal control. Most of our knowledge about the hierarchical network of supraspinal locomotion centers derives from animal experiments, mainly in the cat. Here we summarize evidence that the supraspinal network of quadrupeds is conserved in humans despite their transition to bipedalism.

METHODS: A total of 45 subjects were examined during three different studies using mental imagery of locomotion in fMRI in sighted healthy adults (n=38, [1, 2]) and congenitally blind subjects (n=7, [3]). Subjects were trained to perform (eyes open) and then to imagine (eyes closed) these four conditions: lying (rest condition), standing, walking, and running. The experimental procedure is described in detail in [2]. Functional imaging was done immediately after the training using a standard clinical scanner (1.5 T Siemens Magnetom Vision, Erlangen, Germany).

RESULTS: By use of mental imagery of locomotion in fMRI we found: (1) locomotion modulates sensory systems and is itself modulated by sensory signals. During automated locomotion in healthy subjects cortical sensory inhibition occurs in vestibular and somatosensory areas; this inhibition is cancelled in the congenitally blind; (2) we delineated separate and distinct areas in the brainstem and cerebellum which are remarkably similar to the feline locomotor network. The activations found here include homologues to the pacemakers for gait initiation and speed regulation in the interfastigial cerebellum and bilateral midbrain tegmentum (cerebellar and mesencephalic locomotor regions), their descending target regions in the pontine reticular formation, and the rhythm generators in the cerebellar vermis and paravermal cerebellar cortex.

CONCLUSIONS: This conservation of the basic organization of supraspinal locomotor control during vertebrate phylogeny opens new perspectives for both, the diagnosis and treatment of common gait disorders. It is conceivable that electrical stimulation of locomotor brain stem centers may initiate and improve gait in selected patients suffering from Parkinson's disease or progressive supranuclear palsy.

ACKNOWLEDGEMENT: This work was supported by the Deutsche Forschungsgemeinschaft (DFG JA1087/1-1).

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P.13

Proprioception of postural joint rotations: the consequences of short range muscle stiffness and fluctuating muscle activity in relation to human standing

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INTRODUCTION: High-quality proprioception comes from muscles and tendons. Tendon compliance, muscle stiffness and fluctuating activity complicate the transduction of joint rotation to a proprioceptive signal. These problems are particularly acute in postural regulation because of tiny joint rotations and substantial short-range muscle stiffness. When studying locomotion or perturbed balance these problems are less applicable. We recently measured high short-range-stiffness in standing and considered the implications for load stability [1, 2].

METHODS: Here, using an appropriately simplified model, measurements of short range muscle stiffness [2] and fluctuations in muscle length measured from quiet standing [3] we analyse the conversion of joint rotation to spindle input and tendon tension while considering the effect of short-range-stiffness, tendon compliance, fluctuating muscle activity and fusimotor activity.

RESULTS: Basic principles determine that when muscle stiffness and tendon compliance are high, fluctuating muscle activity is the biggest factor occluding registration of small postural joint rotations. Passive and un-modulated muscle, uncomplicated by active length fluctuations, enables much better registration of joint rotation and requires fewer spindles. Short-range muscle stiffness is a degrading factor for spindle input and enhancing factor for Golgi input. Constant fusimotor activity does not enhance spindle registration of postural movements in actively modulated muscle: spindle input remains more strongly associated with muscle activity than joint rotation. A hypothesised rigid α-γ linkage could remove this association with activity but would require large numbers of spindles in active postural muscles. Using micro-neurography, existence of a rigid α-γ linkage could be identified from the correlation between spindle output and muscle activity. Basic principles predict a proprioceptive “dead-zone” in the active agonist muscle that is related to the short-range muscle stiffness.

CONCLUSIONS: During quiet standing, in the actively modulated agonist, the relationship between ankle joint rotation and muscle-proprioceptive input is highly ambiguous. This differentiates quiet standing from platform translation and platform rotation experiments where joint rotations are likely to be much larger.

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P.14

Online visual control of reach-to-grasp reactions evoked by unpredictable balance perturbations

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INTRODUCTION: Reaching to grasp an object for support is a common and functionally important response to sudden balance perturbation [1]. The need to react very rapidly (to prevent falling) imposes temporal constraints on acquisition and processing of the visuospatial information (VSI) needed to guide the limb movement. Previous results [2] suggest that the CNS may deal with these constraints by using VSI stored proactively, prior to perturbation onset (PO); however, the extent to which online visual control is necessary or sufficient to guide these reactions has not been established. In this study, we examine the speed and accuracy of perturbation-evoked reach-to-grasp reactions under conditions where the CNS is forced to rely entirely on either stored or online VSI.

METHODS: Reach-to-grasp reactions were evoked via sudden unpredictable forward and backward platform translation, in healthy young (age 20-30) and older (age 65-75) adults. In each trial, a motor-driven device mounted on the platform controlled a cylindrical handhold (20cm long) to move unpredictably along a transverse axis in front of the subject, to one of four locations (left or right of midline; distance from midline = 50% or 75% of shoulder width). PO was then triggered after a random delay (2-5s). Subjects were instructed to recover balance by grasping a marked “target” section of the handhold (length=125% of hand width) as quickly as possible; foam barriers deterred step reactions. Three visual conditions were tested, using liquid-crystal goggles to occlude vision: 1) prior to PO (forcing use of online-VSI), 2) after PO (forcing use of stored-VSI), or 3) not at all (normal-VSI). The analysis focussed on the forward-translation (backward “fall”) trials. Prior to the main protocol described above, subjects performed five initial trials in which vision was unrestricted. In the last of these five trials, additional lateral motion of the handhold (8cm, over an interval of 300ms) was introduced unexpectedly, beginning 200ms after PO. EMG, motion analysis and hand-contact sensors mounted on the handhold were used to characterize the arm reactions.

RESULTS: Initial trends reported here are based on three young-adult subjects; full results from 12 young- and 12 older-adult subjects will be presented at the meeting. The three initial subjects grasped the handhold with similar accuracy in all three visual conditions (hand landed on target area in 77-81% of trials); however, forced reliance on online-VSI led to substantial delay in contacting the handhold (average time to contact: 548ms versus 493ms for normal-VSI and 507ms for stored-VSI). Two subjects were able to grasp the target successfully despite the unexpected post-PO handhold motion; however, the third subject made no overt attempt to alter the original hand trajectory.

CONCLUSIONS: The similarity between stored-VSI and normal-VSI responses suggests that stored-VSI was sufficient to control the reach-to-grasp reactions and that online VSI was not required. It appears that it is also possible to rely entirely on online visual control to guide (or modulate) the reach; however, response completion was delayed substantially (by ~50ms) in online-VSI trials. Presumably, this delay was needed to provide sufficient time for the online acquisition and processing of the VSI needed to guide the arm reaction. This capacity to delay grasp completion, without falling, may have required up-regulation of the stabilizing lower-limb reactions. Further analysis will be performed to examine this possibility. We anticipate that the older adults will have reduced capacity for such up-regulation, and hence may be less able to maintain stability, particularly since their grasp reactions will likely be less accurate and slower.

ACKNOWLEDGEMENTS: Canadian Institutes of Health Research (grant #MOP-13355), Ontario Neurotrauma Foundation, Vision Science Research Program (Toronto).

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P.15

Visuomotor control of step descent: evidence of specialised role of lower visual field

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INTRODUCTION: We often descend steps and stairs successfully and safely in the absence of visual feedback from the feet and lower-limbs. For example, when we step down from a curb onto the road, we typically tend to look if there is any oncoming traffic. Therefore, the present study examined whether visual information from lower visual field (lvf) provides any advantage to 'fine tuning' landing during step descent.

METHODS:10 healthy adult subjects (age 24.4 ± 9.4 yr) completed repeated step downs over 3 step heights with visual information available from either full or upper visual fields (lvf occluded), for specific intervals relative to step initiation. Visuomotor control of step descent was assessed by determining pre-landing kinematic measures and landing mechanic variables for the initial landing period.

RESULTS/DISCUSSION: When lvf was restricted, kneedrop decreased and occurred earlier in the descent (figure 1) and $Fz_{peak,}$ and knee and ankle angular velocity during initial landing were reduced. This suggests that when visual cues from the lower visual field were restricted, individuals were unable to effectively use visual cues from areas of the upper visual field, such as those relating head position to the environment, to guide/control landing in the same manner as occurred under full vision. These changes are consistent with participants being uncertain regarding precise floor height when access to lvf was restricted, which resulted in them adapting their landing behaviour but without fundamentally altering their stepping strategy (e.g. there was no change in lower-extremity stiffness or CM positioning when lower visual field was restricted). Compared to when vision was available throughout, the occlusion of vision from toe-off or mid-swing caused very few differences in landing behaviour. The finding that only the magnitude and timing of kneedrop was altered when vision was unexpectedly occluded from mid-swing onwards, suggests that most of visuomotor control of step descent occurs prior to or during movement initiation and that landing behaviour only requires subtle 'fine-tuning' using on-line vision in the latter portion of the descent phase. A trend of increasing foot angle across vision conditions (p=0.07) suggests that the changes in kneedrop parameters when vision was occluded from mid-swing onwards, arose to make sure landings occurred more 'on the toes' and thus that unexpected landings were not associated with an increased peak landing force (landing force was constant across vision conditions).

CONCLUSIONS: These findings indicate that the visuomotor control of step descent takes advantage of information from the lower visual field when available, and that such information is predominantly used during movement planning.

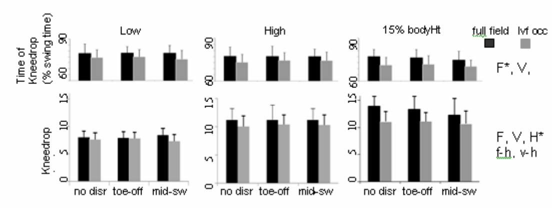

Fig. 1 Group mean kneedrop time and distance across conditions. Significant factors are shown by letter (p < 0.05) and asterisk (p < 0.001), for step height (H), field (F) and vision condition (V).

P.16

Human gaze control during walking over obstacles

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INTRODUCTION: Visual scanning of the environment is important for safe locomotion. Avoiding hazardous situations, such as walking over obstacles, implies an additional requirement to human coordination. Patients with neurological diseases as spinal cord injuries or vestibular problems show a higher risk of falling [1] because of deficits in coordination (e.g., in balance). These patients depend even more on visual input compared to healthy subjects. We hypothesize that gaze behaviour during walking over obstacles is different. However, before we study patient groups, we first determine the characteristic gaze pattern in healthy subjects when stepping over obstacles.

METHODS: Subjects walked on a split-belt treadmill with two obstacle-machines for repetitive stepping over a right and a left obstacle (two foam sticks, 18 cm above floor). Force sensors under the treadmill allowed the detection of right and left heel strike, which triggered randomly the start of the right or left obstacle, respectively. Simultaneously with the trigger, an acoustic warning signal sounded. Optionally, the level of foot clearance was measured and corresponding acoustic feedback tones of different frequencies were given to the subjects.

Subjects wore a video-oculograph (EyeSeeCam) with two eye-cameras, one infrared sensitive head-camera, and one gaze-camera [2]. A servo driver aligned the gaze-camera parallel to eye-movements in order to record images from the subject's perspective. The head-camera scanned five infrared LEDs, invisible to the human eye and located on a plane in front of the treadmill. These LEDs spanned a vector space, in which the gaze focus points and the head position were defined. Each subject had to complete three trials with conditions as follows: 1) walking at a preferred speed and crossing the obstacles with foot clearance as low as possible, 2) walking at 2.5 km/h, and 3) walking at 4.5 km/h. For conditions 2 and 3, the level of foot clearance was irrelevant. Recorded were a) direction of gaze in the sagittal plane, b) head position in the sagittal plane, c) ground reaction forces on the treadmill to determine the gait phases, d) triggers of the obstacles and e) foot clearance.

RESULTS: First results show that subjects were permanently focusing the obstacle (located about 70 cm ahead of the subjects) between obstacle releases. They follow the obstacle with their eyes almost till stepping over. Further results and conclusions will be presented at the ISPGR conference.

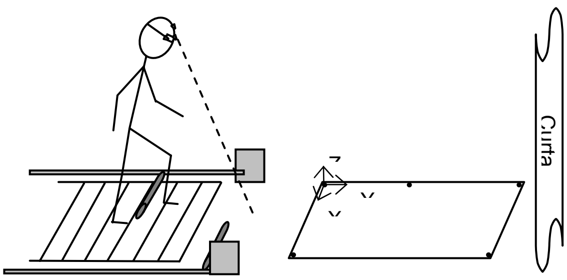

Fig.1 Experimental set-up

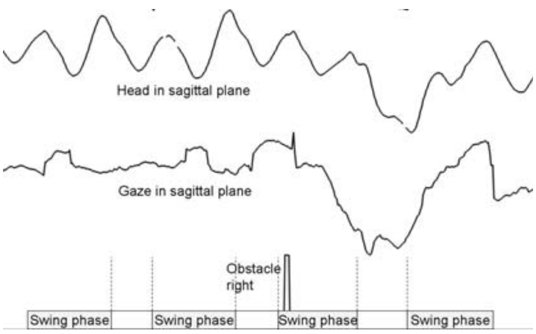

Fig.2 Averaged pattern of one subject

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P.17

The influence of vestibulo-visual integration on postural stability during standing

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INTRODUCTION: Previous studies separately using galvanic vestibular stimulation (GVS) and optokinetic stimulation have shown that the independent perturbation of vestibular and visual afferent information induces a lateral postural displacement. Combined stimulations of vestibular and leg proprioceptive afferents have shown that the postural response is similar to the vector sum of the responses obtained after each stimulation applied alone [1]. The aim of the present study was to identify the contributions of integrated visual and vestibular information on postural control during standing.

METHODS: Postural stability of 8 healthy adults (4 men and 4 women, 30.5 +/- 9.73 years) was measured in different conditions. Subjects were asked to fix their gaze on a 14.5 cm-diameter target projected at eye level on a 3.35m x 2.50m screen placed 1.3 m in front of them. The visual conditions involved unperturbed vision (UV) or an optokinetic stimulation (OS; clockwise rotation of cluster field at 30°/s). Using a Grass S88 stimulator connected to an isolation unit, GVS was administered for 10 seconds using a tonic, transmastoidal current of 1 mA, but only the last 5 second period of the stimulation (steady-state) was analyzed. For each visual condition, different vestibular conditions were assessed: no stimulation (NS), GVS right (GR) or GVS left (GL). The six conditions, therefore, were: no sensory stimulation (NS_UV), independent sensory stimulations (NS_OS, GR_UV and GL_UV) and combined sensory stimulations (GR_OS and GL_OS). A Polhemus system (Fastrak magnetic tracking device) tracked angular movement (roll) of sensors placed on the head (H) and trunk (7th thoracic vertebra; T). Force platforms (AMTI model OR6-5) were also used to evaluate the lateral displacement of the centre of pressure (CoP) in the frontal plane.

RESULTS: Our data show a lateral postural deviation toward the anode side for the head, trunk and CoP for the independent GVS stimulations. The optokinetic stimulation also caused a lateral displacement of the head and trunk towards the right, but the displacement of the CoP observed was not different from NS_UV ($p=0.484$). The lateral postural deviations of the head and trunk were similar for each sensory stimulation to the right (NS_OS and GR_UV: H: $p=0.123$; T: $p=0.484$), but lower for GR_UV than the combined GR_OS for the head (H: $p=0.025$; T: $p=0.093$; CoP: $p=0.889$). The summation of the mean displacements during

NS_OS and GR_UV was comparable to the combined stimulations in the same direction (GR_OS: H: p=0.674; T: p=0.263; CoP: p=0.674). Furthermore, the summation of NS_OS and GL_UV was similar to the combined stimulations in opposite directions (GL_OS: H: p=0.337 T: p=0.263; CoP: p=0,889) and the postural displacement observed in GL_OS was comparable to NS_UV (H: p=0.208; T: p=1.000; CoP: p=0.208).

CONCLUSIONS: When applied together, vestibular and visual stimulations generated a similar response as was found for the summation of independent stimulations. Although some initial sensory re-weighting for the present visual environment (i.e., with reduced lighting) may have occurred, the integration of vestibular and visual afferent information appears to involve a summation of individual effects regardless of the direction of the independent sensory stimulations. This result is similar to what has been found for combined vestibular and proprioceptive stimulations [1]. Furthermore, the present analyses suggest a possible difference between the effects of visual and vestibular afferent information on lower body control.

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P.18

Foot anatomy specialization for postural sensation and control

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INTRODUCTION: Anthropological and podiatric research suggests that the human foot is uniquely designed for propulsion and support. This research has shown that bi-pedalism is more efficient than quadripedalism because energy is stored in the foot arch for propulsion. With over a hundred muscles, tendons, and ligaments, 26 separate bones, and 33 joints, the foot and specifically the arch likely evolved for as specialized a role as the thumb and fingers did for fine manual control. However, despite this, most postural studies tend to focus on the simple hinge action of the ankle joint. We hypothesize that the arch and toes play an important role in postural control.

METHODS: To investigate this question, we made kinematic, center of pressure, and electromyography measurements of the lower extremities during quiet stance and perturbed posture. We first quantified the deformation of the foot arch under stationary loading (n=7) with subjects seated, feet placed on a force plate, and knees flexed at a 90° angle. A displacement probe was placed on the dorsum of the foot approximately over the cuneiform bones but avoiding the dorsiflexor tendons (e.g. extensor hallicus longus), which measured the change in the height of the foot arch when we placed and lifted a 10kg weight on the knee. Secondly, using the displacement probe on the foot dorsum, an angular potentiometer attached to anterior tibia to detect shin A/P sway, and a force plate to measure center of pressure, data were collected during quiet stance with eyes closed for 60s (n=7) to establish the relation between body sway and foot arch deformation. In a third set of tests designed to differentiate functional roles of the foot anatomy, we compared how perturbations to the toes versus the heads of 1st and 2nd metatarsal (MT) affected postural control while standing eyes closed (n=12). The subjects' hind-foot was on a stable, fixed force plate, while the forefoot was on a moveable surface. In the TOES condition, the head of the MTI/II as well as the hind- and mid-foot was on the fixed platform while the first three phalanges were on the moveable platform. In the MT condition, the phalanges and 1st and 2nd MT were both on the moveable platform while the hind-foot remained on the fixed platform. Perturbations entailed a 2.5-10 mm upward shift at 2.5 mm/s of the anterior moveable platform.

RESULTS: The results showed that loading and lifting the 10kg weight on the knee respectively lowered and raised the foot arch between 1-1.5mm, of which less than 50% could be accounted for by plantar surface skin compression. Analysis of the foot arch deformation and the shin sway revealed a significant correlation between the two measures ranging from r=0.7 to 0.9 (p<0.0001) during quiet stance showing that as the tibia tilts forward the foot arch flattens and vice versa. EMG measures of the anterior tibialis, gastrocnemius/soleus, and erector spinae revealed measureable changes in muscle activity corresponding to the perturbation, despite the fact that ankle joint was not perturbed because the hind-foot was always on a fixed, stable support. The EMG responses were larger and more evident in the MT versus TOES condition, with less than 7% showing no clear EMG response in the MT condition while 14% showed no response in the TOES condition. The RMS variability of shin sway increased significantly in both the TOES (p<0.0002) and the MT conditions (p<0.00001), when compared to baseline variability during QS. However, the increase in RMS was significantly greater in the MT condition (p<0.009). The RMS does not return to baseline level for at least 30s.

CONCLUSIONS: The foot, rather than serving as rigid base of support, is in flexible, active state and is sensitive to minute perturbations even if the entire hind- and mid-foot is stably supported and the ankle joint is unperturbed. The slow return to baseline posture after a very small perturbation to the phalanges or the 1st and 2nd MT appears to change the surface reference frame which takes time to reestablish. These findings suggest that the foot and its anatomical architecture are uniquely designed for and integral to performing the complex task of bipedal postural control.

P.19

Effect of scene complexity on optic flow perception: preliminary results

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INTRODUCTION: Despite the abundant amount of research on the visual perception of optic flow, designing a virtual scene for the evaluation or treatment of balance disorders remains a challenge. Several key concepts have been identified [1-2], but it is still unclear whether a richly animated scene with ample environmental cues will have an enhanced effect on locomotor steering, as compared to a hyperspatial scene with random spheres. We hypothesize that a more ecological virtual environment will lead to better perception using optic flow for heading reorientation.

METHODS: Four healthy subjects were instructed to walk straight for 5m in either (1) a rich-textured virtual scene simulating a 4m x10m room with abundant vertical and horizontal cues or (2) a random spheres-filled hyperspace scene of the same dimension, projected in a helmet-mounted display unit (NVisor). After walking 1.5m, the focus of expansion (FOE) of the virtual scenes was rotated either towards the left (-40°), the right (+40°) or remained straight ahead (0°). A 12-camera Vicon system was used to record body segment movements and body center of mass trajectory was calculated using the plug-in gait model.

RESULTS: When subjects were immersed in the virtual room (ecological scene), they changed their heading direction in the physical world in the direction opposite to the rotation in FOE, thus reorienting relatively straight ahead within the virtual environment. In the hyperspace scene, the physical deviations were smaller in amplitude, and trajectories presented more directional errors than in the ecological scene.

CONCLUSIONS: This study suggests that the complex nature of visual information has an important impact on the perception of optic flow, and hence heading reorientation. Thus, in the creation of virtual environments for treating balance disorders, it is essential to take into consideration the complex contextual factors and simulate closely the functional physical environment.

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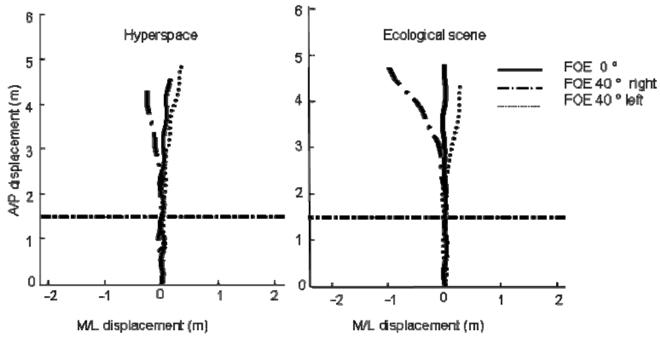

Figure 1 – Representative center of mass trajectory in the horizontal plane from one subject walking in the hyperspace scene of random spheres (left) vs the ecological virtual environment (right).

P.20

Does the non-glabrous skin on the dorsum of the ankle in humans have a role in position sense?

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INTRODUCTION: It is increasingly evident that cutaneous receptors are capable of providing proprioceptive cues signalling joint position and kinesthesia at various joints in the human body [1-4]. Applied skin stretch mimicking joint motion has been shown to evoke illusory sensation of movement at the finger, knee and elbow [3]. Most studies that have focused on the proprioceptive role of nonglabrous skin receptors have investigated the upper limb [3] or the knee [2-4] resulting in a paucity of data from skin surrounding the ankle joint. It is of particular importance to evaluate the role of cutaneous receptors to proprioception at the ankle as this joint plays a crucial role in postural control [5]. The aim of the study was to reduce the cutaneous sensation on the dorsum of the foot and ankle and thus isolate the contribution of that area of skin to joint position sense.

METHODS: Healthy subjects were seated while their left ankle was passively rotated in plantarflexion (PF) and dorsiflexion (DF) to 4 different target angles (5°, 10°, 15° and 20° PF and DF). In each control trial the left ankle was rotated to a target angle which was held for 3 s before the return to a neutral position. The right ankle was then passively rotated in the same direction and subjects indicated when the target angle was reached. After the control trials, topical anesthetic (EMLA ®) was applied to a 15 cm^2 area of skin on the dorsum of the left foot and ankle and the protocol was repeated (test trials). Prior to the test trials the sensory threshold of the anesthetized skin was reduced to 115 mN; equivalent to recorded sensory neuropathies [6]. Surface EMG was recorded bilaterally from the soleus and tibialis anterior muscles to ensure no muscle activity during the passive rotations. Two goniometers (Biometrics) were attached to the lateral aspect of the leg and foot to record ankle angular displacement.

RESULTS: The error between the target and matching angles increased when cutaneous sensation was reduced. The absolute matching error increased from an average of 1.95° (S.D. 1.6°) during the control trials to 3.33° (S.D. 2.2°) after application of the anesthetic. During anesthetized trials angles were consistently undershot as compared to control trials. (-2.9° in DF; -1.5° in PF).

CONCLUSIONS: The conservative matching angles during the anesthetized trials indicate that subjects perceived less ankle rotation when the topical anesthesia was applied. Overall, the increase in matching error after the skin was anaesthetized suggests that skin may play a role in proprioception at the ankle joint. Future research is needed to determine whether the proprioceptive role of skin is independent or whether it may be a result of a cutaneous influence on the sensitivity of muscle spindles.

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P.21

Preferential loss of distal large-fibre afferents after pyridoxine intoxication and the role of ganglion cell size in determining neuronal vulnerability

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INTRODUCTION: Toxic doses of pyridoxine elicit a selective neuropathy of large somatosensory, including group I muscle, afferents, while motoneurones are not compromised. In the cat, the sensory loss is associated with severe motor deficits [1]. After the initial trauma the experimental animals recover and may re-gain, after several months, some locomotor capability. Since there is no evidence of direct neurotoxic effects of pyridoxine on the CNS, the acute deficit must be attributed to the loss of peripheral sensory feedback, and the recovery to major plastic compensation in the sensorimotor CNS. However, the size of the deficits (both acute and persisting) is not uniform, topographically. Limb movements are compromised more severely than head, neck and trunk movements. Yet in lumbo-sacral dorsal root ganglia (DRG) the largest ganglion cells are lost preferentially, if not selectively, suggesting that susceptibility to intoxication increases with cell size. This then begs the question, why group I afferents of distal muscles should be more vulnerable than those of axial muscles.

METHODS: The innervation of cat muscle spindles and Golgi Tendon organs (GTO) of m. longissimus capitis (LC, neck), m. extensor caudae lateralis (ECL, trunk) and m. gastrocnemius medialis (MG, hind limb) was examined at different stages of motor recovery. Spindles and GTOs were teased from silver impregnated muscles, and primary and secondary spindle endings were identified by their size and characteristic innervation pattern of the receptor organ.

RESULTS: Generally, there was extensive loss of primary spindle and GTO endings and variable loss of secondary endings. For comparable motor deficits, the extent of spindle denervation was independent of survival time. This argues against regeneration contributing significantly to motor recovery. Further, there was a remarkable correlation between the magnitude of the acute motor impairment and the extent of spindle denervation. Superimposed on this general pattern, there was a clear axial gradient of sensory afferent vulnerability: 1) in neck muscles (LC) sensory loss was limited to spindle primary endings; 2) in axial trunk muscles (ECL) spindle primary as well as GTO endings were lost almost exclusively; 3) in distal limb muscles (MG) larger proportions of group I and a significant fraction of group II (secondary spindle) afferents had degenerated. A simple mathematical model of the determination of neurone size (ganglion cell volume) by the metabolic demands of different neurone compartments largely accounts for the observed axial gradient of sensory loss, since the peripheral axon volume may be up to 100 times larger than the ganglion cell soma volume and since the axon appears to be the by far most demanding neuronal appendix. Specifically, calculated soma volume of the longest IA afferents (distal limb) could easily exceed that of short axial IA afferents by a factor of 10.

CONCLUSIONS: 1) While the cellular mechanism of pyridoxine neurotoxicity is not known, the present observations are compatible with the notion that the magnitude of a sensory neurone's metabolism is a critical risk factor. Since the cellular metabolism is likely to increase steeply with axon length and diameter, it is very plausible that the neurones with the largest (i.e. group I) diameter and the longest axons (i.e. those from distal limb regions) are most susceptible to toxic insult. 2) The massive motor deficits elicited by the loss of a relatively small fraction of sensory afferents (those with large and long axons) are in line with the notion of a critical importance of proprioceptive feedback for the control of voluntary movement.

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P.22

The temporal coupling between limb movements and gaze during precision stepping is preserved over different step size and gait speed conditions

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INTRODUCTION: Precise foot placement is a requirement for safe ambulation over complex ground terrain, and depends on accurate visual information on upcoming landing areas. Whereas previous studies on precision stepping have shown a clear temporal linkage between eye and limb movements [e.g. 1,2] it is as yet unclear how these oculomotor-locomotor couplings are modified in response to (i) step length and (ii) speed requirements.In two experiments we tested whether the time and distance sampled ahead was affected by imposed step size (exp. 1) and/or the speed of progression (exp. 2).

METHODS: In experiment 1, subjects (7 males, body height 185-195 centimetres) were required to step on specified targets while step length varied over trials (42, 70, or 98 cm), and gait speed was held constant (± 4.0 $ms^{-1)}$. In experiment 2, subjects (n=7) stepped on equidistant targets (82 cm) in 3 gait speed conditions (3.6, 4.5, and 5.3 ms^{-1}). In both experiments, gaze data (head mounted eyetracker, ASL) and 3D position data (Optotrak) were recorded simultaneously.

RESULTS: The results of experiment 1 showed that the distance looked ahead increased with step length, but that the latency between target fixation and foot placement did not change over step size conditions. Conversely, in experiment 2, the latency between target fixation and foot placement decreased with gait speed, whereas the distance looked ahead was similar in the three gait speed conditions. However, regardless of the imposed step length (exp. 1) or speed of progression (exp.2), subjects always looked approximately 1 step ahead and fixations on upcoming targets were initiated during the preceding stance phase of the stepping limb. To maintain this coupling between gaze and limb movements over different gait speed conditions, subjects chose to modify the duration of target fixations (i.e. shorter durations at higher speeds) rather than to modify the distance over which visual information was sampled.

CONCLUSIONS: These experiments show that the visual sampling strategies used during continuous precision stepping are not planned in absolute spatial coordinates and do not depend on time to contact information, but instead involve a temporal coupling between gaze and the momentaneous pattern of limb movements. This coupling allows for a combination of feed forward and online visual control of the stepping foot, which facilitates accurate placement of the foot on the landing.

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P.23

Where and how far ahead do we look when we ascend or descend a staircase?

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INTRODUCTION: Stair ambulation is presumably under strong visual control and clinical studies indicate that visual factors are important determinants of falling accidents on stairs. However, it is as yet unknown where people look when they ascend or descend stairs. In this study we assessed what features of the environment are considered important for stair ambulation and how far people look ahead when walking up and down a staircase.

METHODS: Six healthy young subjects walked up and down a staircase (Ten treads; Riser: 18.0 cm; Tread: 28.0 cm; Width: 106 cm; Inclination: approx. 33 degrees) taking the stairs either one or two steps a time. A head mounted eye tracker and an external video camera were used to record gaze and position, respectively. Gaze data were classified with respect to 4 fixation locations: (1) tread surface, (2) tread edge, (3) level surface at the end of the staircase, and (4) 'elsewhere'.

RESULTS AND CONCLUSIONS: The main results (figure 1) can be summarized as follows: Stair ascent and descent were each associated with different visual sampling strategies. During stair ascent more time was spent fixating environmental elements that were irrelevant to the task than during stair descent, indicating that stair descent is under stronger visual control. Also, fixations on the edges of treads were made more frequently during stair descent, suggesting that the edges of stair treads provide important information when walking down stairs. These findings may help to better understand why visual factors (e.g. reduced contrast sensitivity, wearing bifocal glasses) are associated with falling accidents particularly when walking down stairs.

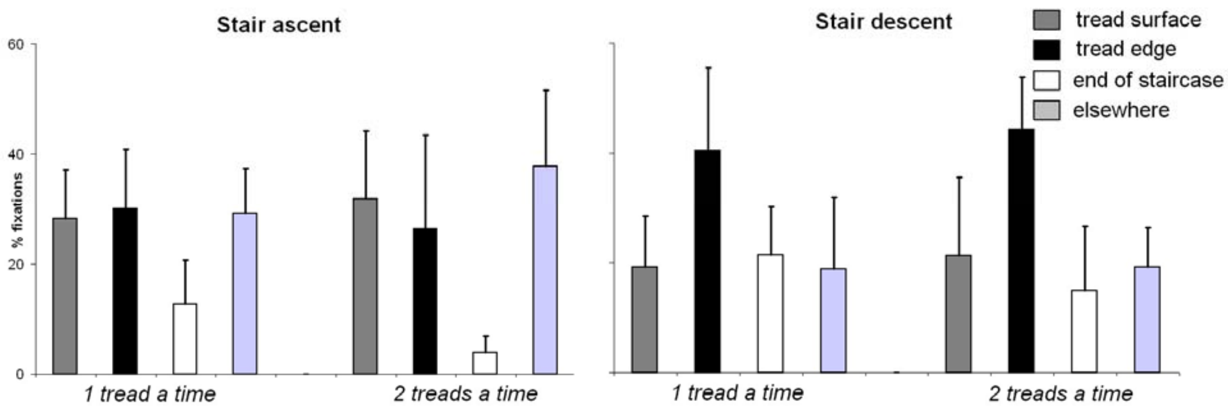

Fig. 1 Fixation durations expressed as % of total fixation time

The number of foot steps looked ahead was different for conditions in which stairs were taken one (4.29 ± 0.8) or two treads (1.83 ± 0.4) a time. However, when expressed as the number off stair treads the distance looked ahead was comparable for both tasks (4.33 for one, and 3.67 for two treads a time) indicating that people look a fixed number of stair treads, rather than foot steps, ahead. Since in precision stepping over level ground gaze behaviour is tightly linked to the step cycle, it can be concluded that during stair stepping different visual sampling strategies are used than during precision stepping over level ground.

P.24

Pictorial depth perception and postural stability

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Introduction: Postural stability improves when fixating a near than a far target. Visual and oculomotor factors contribute to proximity effect [1,2]. The goal of this study is to examine the possible effect of high-level pictorial depth perception on postural stability.

Methods and Results : ***Experiment 1***. Ten subjects (25.6±6.5 years) took part in the experiment. In each condition they view on a PC screen high quality image of paintings: *'Egypt' or 'O Quarto Cinzento'* from Marie Elena Vieira Da Silva (see Fig.1-a). These abstract paintings provide a strong perception of depth and perspective. Subjects viewed either the painting or its cubist transformation (made with Photoshop, Fig.1-b). All postural parameters (COP surface, lateral and antero-posterior sway, variance of speed) were found to be higher when viewing the painting. Postural results were correlated with subjective evaluation of depth perception (in a scale of 10, group mean appreciation 8/10 for the painting, 2/10 for its cubist transformation).

Control experiment, 2. Sixteen subjects (28.8 ±7.2 years). They viewed on the screen a grid either fronto-parallel or tilted in depth. Tilt of the grid decreased postural stability but only for the antero-posterior sway.

Experiment 3. Subjects viewed on the PC screen the painting *'L'Annunciazione del polittico di Sant'Antonio'* **fr**om Piero della Frrancesca (see Fig.1-c). Four conditions were run: *(a)* fixating the background, at the farthest point in depth; *(b)* fixating the foreground, the closest point; *(c)* and *(d)* same as *a,b* but this time subjects wore convergent prisms (5 diopters per eye). For condition *c*, a strong conflict was induced between perception of perspective and ocular motor signals resulting from high convergence. Postural stability (COP surface measure) was found to be significantly better when fixating at the foreground (b) than at the background (b). With prisms, however, postural stability was good for both background (c) and foreground fixation (d)

Conclusions: Pictorial perception of depth and perspective can induce postural instability. This could reflect difficulty in controlling posture in the presence of conflict between 2D and 3D visual cues; it could also be an active response to depth increasing aesthetic pleasure. The weaker effect for the non-aesthetic grid stimulus supports the latter interpretation. However, ocular motor convergence signals (efferent or afferent) induced by prisms can override pictorial cues and stabilize posture.

Acknowledgements: Support by Complex Systems Institut, Paris-Ile –de-France

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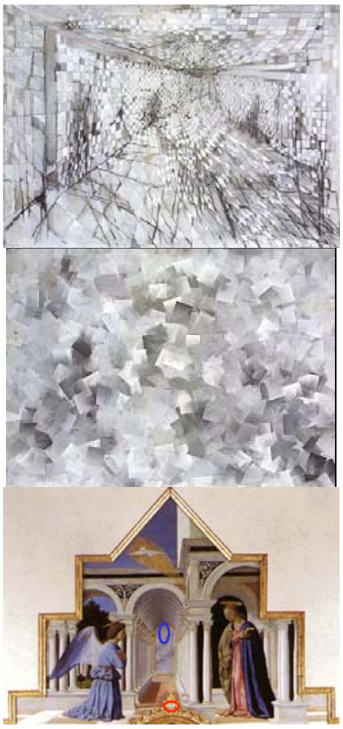

Fig.1 Top to bottom: a) 'O Quarto Cinzento'; b) Cubist trasformation of the above; c) 'L'Annunciazione del polittico di Sant'Antonio'.

P.26

Does increased postural threat lead to more conscious control of posture?

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INTRODUCTION: Increasing the height at which a person stands has been successfully used to explore the effects of postural threat on postural control [1]. Although it is well established that postural threat modifies postural control, little is known regarding the underlying mechanism(s) responsible for these changes. It is possible that changes in postural control under conditions of elevated postural threat result from a shift to a more conscious control of posture. The Movement Specific Reinvestment Scale, including conscious motor processing (CMP) and movement self consciousness (MSC) subscales, assesses the amount to which people consciously control their movements and has been linked to fall risk [2]. We modified this scale to allow us to examine state-specific changes in movement reinvestment. This study investigated movement reinvestment and postural control when standing under different levels of postural threat to determine if there is a relationship between these variables.

METHODS: Forty-eight healthy young adults stood as still as possible on a force plate with arms at the sides and eyes open for 60-s. The toes were placed at the anterior edge of the force plate and stance width was defined by the participant's foot length. The force plate was positioned at the edge of a hydraulic lift platform. Postural threat was manipulated by changing the height at which individuals stood: ground level (LOW) and 3.2-m above ground level (HIGH). Balance confidence was assessed prior to each stance trial. Fear, anxiety, stability and movement reinvestment were assessed after each stance trial. Summary measures calculated to quantify postural control were the mean position (MP), root mean square (RMS) and mean power frequency (MPF) of the centre of pressure in the anterior-posterior direction.

RESULTS: When standing at the HIGH compared to LOW height, participants felt significantly less confident, more fearful, more anxious and less stable and were more conscious of their movements (i.e., higher CMP scores). A shift in MP away from the edge of the platform and an increase in MPF were observed when threatened. No height effect was observed for RMS. Pearson correlations on difference scores between LOW and HIGH heights revealed a significant relationship between MP and CMP and MSC scores, such that, participants who were more conscious of their movements leaned further away from the platform edge. MPF was significantly related to balance confidence and anxiety (somatic subgroup).

CONCLUSIONS: When performing a stance task at the edge of a high platform, participants were more conscious of their movements. This change in movement reinvestment was only related to one change in posture, leaning away from the platform edge. It is possible that changes in conscious control of posture can influence some aspects of posture but other aspects may be unaffected by these changes (e.g., amplitude and frequency).

ACKNOWLEDGEMENTS: Research supported by the NSERC.

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Manipulating balance efficacy: its effects on perceived and actual balance in healthy young adults

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INTRODUCTION: Research has shown that low balance efficacy, a term often used interchangeably with fear of falling, is related to poor balance, increased fall risk, restriction of activity, loss of independence and reduced quality of life [1]. Although the association of balance efficacy with changes in these health and health-related behaviours is well-established, the causal relationship between low balance efficacy and these behaviours is not well understood. Given the potential reciprocal nature of this relationship, it is important to better understand factors that alter balance efficacy, and its subsequent outcomes. This study was designed to manipulate balance efficacy using verbal persuasion in order to investigate its influence on perceived and actual balance in healthy young adults.

METHODS: Sixty-one healthy young adults were instructed to stand as still as possible on one leg with their eyes closed for as long as possible. Then, participants were randomly assigned to either a high balance efficacy group (n=21, provided with feedback that their balance performance was within the top 20% for their age and gender), a low balance efficacy group (n=20, provided with feedback that their balance performance was within the bottom 20% for their age and gender) or a control group (n=20, no feedback). Participants were assigned to groups regardless of their actual balance performance. Following the balance performance feedback, participants completed the same balance task. Participants rated their balance efficacy prior to each task, and their perceived stability following each task. Stance duration and trunk movements were recorded during each task to provide an estimate of actual balance performance.

RESULTS: The results showed a significant group (3 levels: high balance efficacy group, low balance efficacy group, control) by time (pre, post balance performance feedback) interaction for balance efficacy and perceived stability. Following the balance performance feedback, balance efficacy decreased for the low balance efficacy group (13.5%), increased for the high balance efficacy (11.12%), but did not change for the control group. Following the balance performance feedback, perceived stability increased for the high balance efficacy group (10.62%) but did not change for the low balance efficacy group or control group. The results revealed no significant changes pre and post feedback in the actual balance measures.

CONCLUSIONS: This study suggests that verbal persuasion can be used to successfully manipulate balance efficacy resulting in altered perceptions of stability in healthy young adults. Examining the influence of manipulated balance efficacy using verbal persuasion on perceived and actual balance in a research setting may provide novel ways to change balance efficacy in a practical setting.

ACKNOWLEDGEMENTS: This study was supported by a grant from NSERC and SSHRC.

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Differential changes in soleus Hoffman and tendon tap reflexes with increased postural threat

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INTRODUCTION: Postural threat associated with an elevated support surface is known to induce stiffer postural control about the ankle joints, yet the mechanism(s) responsible for modulating this response remain unclear. Decreased soleus Hoffman (H-) reflexes have been observed in high postural threat [1] and difficult walking [2] situations. Increased ankle plantar flexor muscle spindle sensitivity, related to altered fusimotor drive has been postulated as a potential mechanism to account for these results. Comparison of H- and mechanically evoked stretch (T-) reflexes can be an insightful, indirect method to investigate muscle spindle sensitivity. The T-reflex is a presumed muscle spindle based reflex, where the H-reflex bypasses the spindle and stimulates the axon directly. We proposed that if postural threat increases muscle spindle sensitivity, then H-reflexes would still be attenuated, but T-reflex amplitude would be increased in a high threat situation.

METHODS: Eight young healthy adults stood braced at the ankles on a hydraulic lift in conditions of low (away from edge 0.8m above ground) and high (at edge 3.2m above ground) postural threat. H- and T-reflexes were pseudo-randomly elicited in the right soleus at a minimum interval of 10s and recorded with EMG. Paired H-reflexes (200 ms inter-stimulus interval) were stimulated with square-wave electrical pulses to the tibial nerve. T-reflexes were elicited with a single 25ms mechanical stretch of the Achilles tendon. Ankle braces served to ensure participants maintained a constant ankle angle for the duration of the experiment. Pilot studies suggest that the braces decrease soleus and tibialis anterior activity and minimize tonic muscular changes and leaning typically associated with standing on elevated surfaces.

RESULTS: T-reflex amplitudes increased in the high compared to low threat condition (mean % change = 27.8%). Paired H-reflexes were both attenuated with increased threat. The first H-reflex amplitude decreased by 24.4% and the second H-reflex amplitude decreased by 37.2% in high compared to low threat conditions. Effect sizes of the T- and H-reflex amplitude changes were all large ($\eta^2 > 0.14$).

There was minimal change in tonic muscle activity in either soleus or tibialis anterior with increased threat.

CONCLUSIONS: The results of this study suggest a differential effect of high postural threat on soleus T- and H-reflexes. Consistent with previous research, H-reflexes were attenuated at height, yet T-reflex amplitudes were increased. The data demonstrate a reflex change independent of background muscle activity. Possible explanations for this include altered muscle spindle excitability independent of overall muscle activation and/or altered motor neuron pool excitability with high postural threat.

ACKNOWLEDGMENTS: This work funded by NSERC.

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Turning emotion into motion: use of Argentine tango dancing to ameliorate depression

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INTRODUCTION: Two thirds of those individuals suffering from anxiety and depression never seek treatment [1]. Many do not wish to be identified as having a mental health problem, while others may not wish to follow psychotherapy or follow pharmaceutical treatment. While cognitive and behavioural therapies may be more acceptable, many individuals search for adjunct alternative therapies in addition to or in place of psychological treatments [2]. One approach that has been shown to be effective is to use activities that incorporate self-acceptance and mindfulness [2, 3]. Mindfulness has been defined widely in literature as the awareness that emerges from focusing and concentrating on the present moment [4]. Meditation is often used by therapists as a mindfulness tool as an adjunct to Mindfulness Based Cognitive Therapy [5]. Also, the physical activity of T'ai Chi Chuan has been used to reduce levels of depression and negative affect [6]. The objective of this pilot study was to investigate whether Argentine Tango dancing, would be as effective as meditation in reducing depression in persons with mild to moderate depression as it requires unity and connection, full awareness of one body, as it is a walking embrace [7].

METHODS: Participants (66) were randomly assigned to meditation, tango dance, or control wait list groups. Self-rating symptoms of depression, anxiety, stress, self-esteem, satisfaction with life and mindfulness were assessed pre and post a 1x (1.5h)/week, 6-week program and 1 month follow-up. Repeated measures ANOVA mixed model was used to determine statistical significance.

RESULTS: An overall time effect for all measures was significant. Positive increases in levels of self-esteem ($F(1,59) = 8.80$, $p=.004$),satisfaction with life ($F(1,59) = 23.61$, $p=.001$) and mindfulness ($F(1,59) = 10.83$, $p=.002$) and significant decreases in depression ($F(1,60) = 27.7$, $p=.001$), stress and anxiety were recorded. These changes were greater for the two experimental groups, but a significant interaction ($F(1,60) = 3.79$, $p=.028$) was found post-intervention for reduced levels of depression in tango and mediation groups as compared to control. There was no significant difference between tango and meditation groups across measures.

CONCLUSIONS: Tango dancing may be an excellent alternative to Meditation for alleviating depression in those with mild to moderate depression, thus providing those who find it difficult to meditate with other alternatives. The prospect of being given mediation or tango dancing lessons is also sufficient to enhance self-esteem satisfaction with life and mindfulness to some degree. However data trends indicated that amelioration in these measures may be much greater for tango and meditation. Future studies should explore this by increasing the duration and intensity of the intervention programs, as well as the number of subjects,

ACKNOWLEDGEMENTS: the Argentine Consul in Sydney AU (P Colombi), Jacqueline Simpson (tango instructor), Tom Jones (Meditation Instructor), Drs Rhonda Brown and Einar Thorsteinsson (UNE, AU).

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Improvements in mediolateral COP during single-support standing balance after cognitive dual-task training in healthy older adults

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INTRODUCTION: There is growing evidence of the involvement of attentional resources in the maintenance of balance in old age[1]. In healthy older adults, neuropsychological measures of speed and executive attention correlate with falls incidence[2]. Together, this literature suggests that interventions to improve executive control ability may have a positive impact on balance control. However, there is no intervention study to date that focuses on improving cognitive processes alone and observing training-related benefits to physical performance.

METHODS: We conducted a training study to examine whether healthy older adults aged 70+ undergoing five sessions of computerized cognitive dual-task training[3] would show significant pre-to-post improvements to standing balance, compared to an untrained control group. In the pre- and post-training sessions, participants performed a single-leg balance task with eyes open, eyes closed, alone, or with a concurrent n-back cognitive load. In the cognitive training sessions, Task A involved a simple colour decision with key press responses, and Task B involved a letter identity decision. Within each one-hour training session, participants performed multiple blocks of single (A or B only) and mixed trials (A, B, or A+B).

RESULTS: We verified first that the Training group improved over the five sessions of dual-task training whereas the control group did not: the Group X Session interaction for pre- versus post-test dual-task reaction time was significant, $F(1, 17) = 29.31$, $p < .001$, $\eta^2 = .633$. Comparing the pre- and post-training balance performances for each group, significant Group x Session interactions were observed for measures of body sway in the mediolateral dimension: speed, $F(1, 17) = 7.61$, $p = .013$, $\eta^2 = .31$; peak-to-peak excursion, $F(1, 17) = 4.64$, $p = .046$, $\eta^2 = .21$; and variability of centre-of-pressure, $F(1, 17) = 5.71$, $p = .029$, $\eta^2 = .25$, such that trained participants reduced their body sway from pre- to post-training sessions but control participants did not.

CONCLUSIONS: The results support the view that postural stability in old age is influenced by central cognitive capacity, and have implications for the design of balance interventions. This study is the first to demonstrate training-related benefits to gross motor performance that stem from a purely cognitive training protocol. The results are consistent with the observation of ability dedifferentiation in old age and support the view that postural stability in old age requires executive control processes [4,5].

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The modulation of working memory capacity through manipulation of postural demands under dual task conditions

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INTRODUCTION: Postural control has traditionally been thought to occur at an automatic level; however, recent research suggests that cortical networks and cognitive processing contribute to aspects of balance. Research using a dual task paradigm, suggests the process of controlling stability requires attentional resources, which are assumed to be limited. Competition for processing resources may occur during the performance of two attentionally demanding tasks and lead to task interference. One aspect of task interference that may occur when an individual performs a postural and cognitive task simultaneously could relate to visual storage capacity limitations, as visual resources are used in the control of both cognitive and postural recovery tasks. Attentional or memory capacity associated with vision can be predicted using a visual memory task. The maximum storage capacity among most young adults is 3-4 items. This value has been demonstrated to be lower among children and the elderly (2 items). No previous work has evaluated whether memory capacity limits could be manipulated by varying postural demand. We hypothesized that memory capacity in young adults would decline when postural demands were gradually increased.

METHODS: Postural conditions of increasing difficulty were evaluated: quiet stance alone, quiet stance trials intermixed with perturbation trials (giving a different mental expectancy) and stance trials during a perturbation (movement of the standing surface) in the anterior-posterior plane. Memory data from conditions 2 & 3 were normalized to the standing condition. The cognitive task was a visual memory task, which probed attentional or memory capacity. Arrays of 4, 6, or 8 squares were viewed for 100ms, followed by a blank screen during which subjects retained in memory the number, position, and color of the array for 900ms. A test array was then presented and subjects indicated if the arrays were identical or different. In perturbed trials, platform movement occurred at the beginning of the memory phase of the visual task.

RESULTS: There was a substantial decrease in memory capacity for nine of the twelve subjects when postural demand increased. There were memory capacity reductions in condition 2 (quiet stance trials interspersed with perturbation trials)(mean reduction: -0.4), compared to condition 1 (quiet stance alone). This suggests that the expectancy of a perturbation to balance reduces memory capacity, and capacity is further reduced by actual perturbation (condition 3) (mean reduction -.5). Figure 1 plots the changes in memory capacity (defined as K-scores) across conditions 1 and 3.

CONCLUSIONS: The results suggest that expected or actual postural threats reduce memory capacity in young adults.

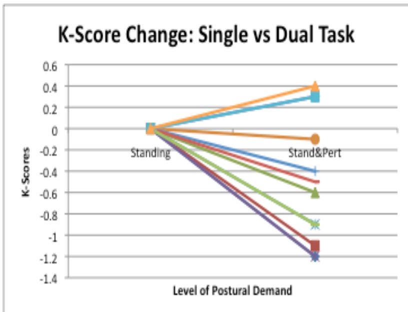

Fig. 1 Modulation of memory capacity

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Influence of chronic pain on gait and cognitive function in older adults: a potential mediator of fall risk?

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INTRODUCTION: Fall risk among older adults is often influenced by mobility problems such as balance and gait impairment. Recent studies suggest that pain may also contribute to fall risk [1], however, the mechanisms underlying this putative relationship are not well-known. Studies in young and middle aged adults have demonstrated that chronic pain (CP) may give rise to cognitive deficits [2] and recent investigations have also highlighted the potential of cognitive changes, in particular executive function (EF), to alter gait and fall risk [3]. Since CP may impair EF and EF may impair dual tasking gait abilities, we tested the hypothesis that CP may act as a distracter or "dual task" and hence interfere with EF and gait in community-living older adults.

METHODS: 245 community-living, healthy older adults (mean: 76.4±4.2 yrs; 60% women) were studied. The Mini-Mental State Exam (MMSE) assessed general cognitive state and the Mindstreams® (NeuroTrax Corp., NJ) computerized neuropsychological test battery quantified sub-domains of cognitive function: EF, motor, memory, and visual spatial orientation. A global cognitive index was also evaluated. Subjects also walked with and without dual tasking, e.g., subtracting 3's. The Berg Balance Test (BBT) and the Timed Up and Go quantified static balance and mobility, respectively. The SF-36 was used to classify subjects as those who reported low levels of CP (>75 on the pain index) and those who reported high levels of CP (<50 on the SF-36 pain index).

RESULTS: Subjects with low (n=154; SF-36 pain score: 92.2+/-8.4) and high levels (n=31; SF-36 pain score: 37.1+/-10.3) of CP were not significantly different (p>0.10) with respect to age, years of education, BMI, MMSE score, comorbidities, or # of prescription medications. The neuropsychological battery did not reveal significant differences in the global cognitive score, memory, motor, or visual-spatial function indices, however, subjects with high levels of CP had significantly lower (worse) (p<0.02) scores on the EF Index (95.3+/-9.9) compared to those with low levels of pain (100.2+/-10.6). Gait speed tended to be different in the two groups during usual walking (p=0.06), and the group differences became significant during dual tasking (high pain group: 104+/19 cm/s; low pain group: 113+/-21 cm/s; p<0.03). BBT scores were similar (p>0.7) in both groups (overall mean: 54+/-2), but there was a small, but significant (p=0.015) increase in Timed Up and Go times in those with high CP (10.0+/-1.6 sec), compared to those with low CP (9.2+/-1.5 sec). After adjusting for the EF index in multivariate analyses, Timed Up and Go times and gait speed during dual tasking were no longer related to pain group. In contrast, adjusting for memory did not change the association between pain group and these two measures of mobility.

CONCLUSIONS: While further studies are needed to understand the role of chronic pain in fall risk, the present findings support the idea that pain may alter cognitive function, in particular EF, and gait in older adults, especially under distracting conditions, and that the route from pain to an increased fall risk may involve its demands on EF. It appears that pain may contribute to deficits in EF and in performance of complex mobility tasks that require additional attention and thereby increase the risk of falls.

ACKNOWLEDGEMENTS: This work was supported in part by the NIH (AG14100 and P01 AG004390).

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How does explicit prioritization alter walking during dual tasking? Age effects on gait speed and variability

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INTRODUCTION: The performance of a secondary task while walking (i.e., dual task, DT) alters gait. For example, even healthy young adults may walk more slowly when they perform a DT. Focus of attention on gait or on the secondary DT might mediate this effect, however, the ability to manipulate the focus of attention and its effect on gait has not been well-studied. We investigated the effects of prioritization on walking in healthy young and older adults to evaluate the "default" prioritization scheme employed, the flexibility to change prioritization, and the effects of prioritization on gait.

METHODS: 40 healthy young adults (26.8±1.6 yrs, 20 women) and 16 healthy older adults (72±6.8 yrs, 7 women) were studied. Gait speed and gait variability were evaluated during usual walking and under three additional DT conditions: 1) No specific prioritization instructions, 2) focused attention on the walking task, and 3) focused attention on the "DT". The word generation test (i.e., verbal fluency) served as the DT.

RESULTS: In both age groups, gait speed decreased significantly during DT, compared to usual walking (p<0.001; see Fig. 1). Compared to speed in the DT no instruction condition, gait speed significantly increased when attention was directed to the gait task in the young adults, and a similar non-significant tendency was seen in the older adults. Gait speed tended to decrease when prioritization was given to the cognitive task, compared to the no instruction condition; the effect was apparently larger in the young. In the young adults, gait variability was not significantly influenced by DT or prioritization. In contrast, in the older adults, DT increased gait variability (p<0.01) while prioritization did not alter this. Word generation tended to change according to the prioritization instructions, as expected, but this change did not reach significance.

CONCLUSIONS: The present findings demonstrate that among healthy young adults the effects of DT on gait speed are strongly influenced by the focus of attention. This finding was less salient in the elderly subjects, suggesting that there is an age-associated decline in the ability to flexibly allocate attention to gait. In the default condition, when prioritization is not explicit, gait speed in healthy young and older adults most closely resembles that of the condition when prioritization is given to the DT. At the same time, healthy young adults apparently selectively adhere to the "posture first" strategy; gait variability, a measure of stability, is not affected by DT or prioritization. Healthy older adults, however, apparently do not fully follow the "posture first" strategy, as variability increases with DT, even when gait is prioritized. Interventions designed to reduce fall risk in the elderly whose gait and cognitive abilities may be impaired should take into account these age-associated changes in prioritization to minimize the challenges and risks of dual task walking.

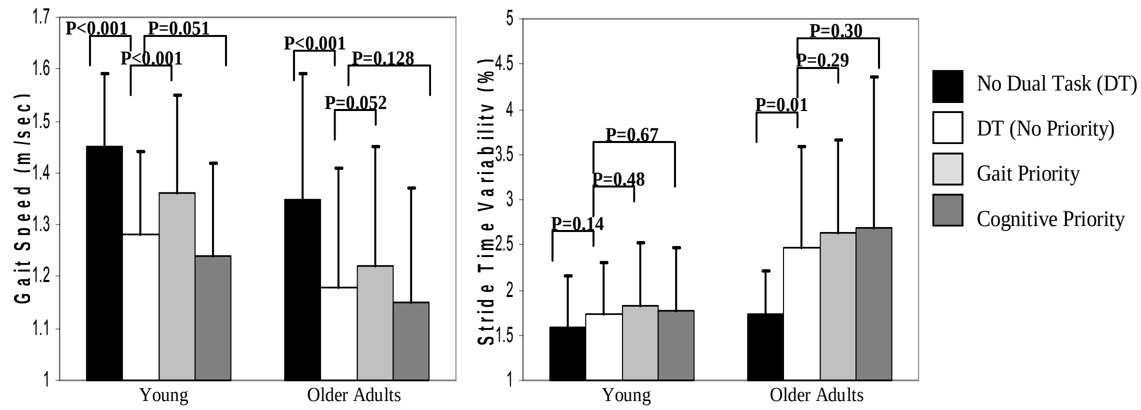

Fig.1 Effects of DT and prioritization on gait speed and gait variability

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Understanding the influence of fear of falling on clinical balance control in community-dwelling elderly individuals.

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INTRODUCTION: Postural threat modifies control of postural sway and induces changes to psychosocial measures in both elderly and young adults [1] Postural threat also results in changes to psychosocial measures and measures of clinical balance control in healthy young individuals [2]. The objective of this research is to examine the effects of postural threat and cognitive load on psychosocial measures and clinical balance performance in elderly individuals.

METHODS: Twenty-five community-dwelling elderly individuals were recruited (age 67-85 (mean 75.96), ten male, fifteen female). Participants completed general fear of falling, self-efficacy, and comorbidity/health questionnaires. The Berg Balance Test and the Timed-Up-and-Go task assessed balance and functional mobility. Participants completed six balance tasks: quiet standing with eyes open (QSEO) and closed (QSEC), one-leg stance (OL), functional reach (FR), tandem standing (TS), and repeated sit-to-stands (STS). Balance tasks were completed at two levels of postural threat: none (tasks performed on the floor) and low (tasks completed on a custom-built wooden platform (50cm high)). Further, tasks were performed with or without a cognitive load (memory task), resulting in a 2 (postural threat) x 2 (cognitive load) design. For each of the four conditions, task-specific questionnaires were completed which addressed anxiety, confidence, stability, and fear of falling. Trunk sway was measured using the SWAYSTAR apparatus. Galvanic skin resistance was recorded from surface electrodes on the hand as a measure of physiological arousal [2].

RESULTS: There was a significant interaction between postural threat and cognitive load on total sway area during QSEO. Increasing postural threat without a cognitive load resulted in a decrease in total sway area, whereas sway area increased with combined postural threat and cognitive load. Total sway area significantly increased during the STS task with increased cognitive load. FR was reduced with increased postural threat. Across all tasks, postural threat and cognitive load were associated with increased physiological arousal and perceived anxiety and decreased balance confidence.

CONCLUSIONS: Clinical balance performance in elderly individuals is affected by both postural and cognitive challenges. Concomitant changes to psychosocial measures related to fear of falling are also seen.

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Effects of temporal predictability of perturbations to standing balance on response time

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INTRODUCTION: Designing paradigms with predictable disturbances to balance allows study of anticipatory factors in the control of postural responses. Previous research [1-2] has shown that response time is independent of prior information regarding the magnitude or orientation of the upcoming disturbance.

METHODS: In order to probe the effects of temporal predictability on response time in standing balance, this study developed a novel balance perturbation paradigm with a regularly spaced series of perturbations. This was contrasted with conditions in which perturbations were introduced in random timing. In addition to the variable of timing certainty, another variable of direction certainty was factorially added with two levels - directed alternately to right and left or randomly. In Experiment 1, a manually-triggered pulley system applied pulls of 3% body weight to hip of nine elderly participants. In Experiment 2, a computer-triggered actuator system applied pulls of 20-mm to hip of six elderly participants.

RESULTS: By using cross-correlation methods, Experiment 1 showed that the temporally predictable perturbations resulted in closer matching of the form of the postural responses with the perturbing forces. However, in both experiments, discrete timing methods revealed that the temporally unpredictable perturbations resulted in a shorter response time. Neither effect of direction certainty nor interaction effect of timing and direction certainties was shown.

CONCLUSIONS: The results evidenced a pre-programming effect of temporal anticipation of disturbance to balance, which may reflect the earlier formation of cognitive representations of the balance stimulus. The shorter response time with temporally unpredictable perturbations was discussed in terms of heightened alertness with uncertain timing, given that a non-threatening magnitude of disturbance is applied.

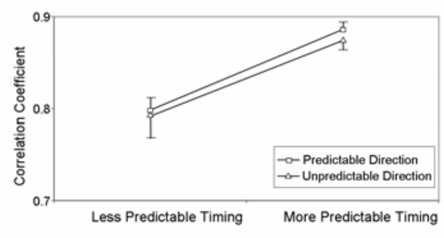

Fig.1 Correlation coefficient between GRF and perturbing forces in Experiment 1

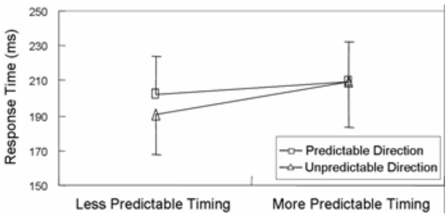

Fig.2 Response time in the four conditions in Experiment 1

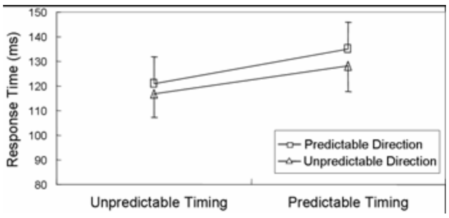

Fig.3 Response time in the four conditions in Experiment 2

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Common and disparate effects of dual tasking in three different motor tasks

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INTRODUCTION: Although gait was previously thought to be an essentially automated process, it is now well known that performance of a secondary, attention demanding task while walking (i.e. dual tasking, DT), affects gait performance in neurological patients, the elderly and even healthy young adults. The question thus arises: what aspects of gait turn it into an attention demanding task? For example, is it a result of the postural control required to maintain an upright position or is it due to the left-right coordination required? To address this issue, we examined whether the ability to divide attention is similar while sitting, standing and walking, whether there is a unique demand of attention dividing while walking and if so, which features of these tasks make them sensitive to divided attention.

METHODS: 20 young healthy subjects performed a word generation task (i.e., verbal fluency) while seated and while performing 3 different motor tasks: 1) seated while pedaling a bicycle, 2) standing on one leg, and 3) walking at a comfortable, self-selected pace. Cycling was quantified using a 3-D accelerometer (JAS Research, USA) placed on a pedal. Standing equilibrium was evaluated using a force plate (AccuSway Plus Platform, AMTI) and a computerized force-sensitive system (B&L Engineering, USA) was used to quantify gait. Parameters related to speed and variability of performance (e.g., stride time, cycle time, RMSSD, SD) were quantified for each task in order to measure the attention cost of the cognitive task on each motor task. Repeated measures analysis of variance was used to compare the tasks with post-hoc paired t-tests.

RESULTS: Some measures of walking and standing were affected by divided attention, however, bicycling was not. For example, walking speed decreased (from 1.30±0.16 m/sec at baseline to 1.19±0.18 m/sec while DT, $p<0.001$) and variability increased during dual tasking (from 1.67% at base line to 2.08% while DT, $p=0.006$). The SD of the center of pressure displacement in the medio-lateral axis increased during DT while standing (from 0.18 mm at baseline to 0.20 mm while DT, $p=0.01$). Bicycling measures of average cycle time and variability of cycling (RMSSD) were both not significantly affected by DT ($p=0.288$, $p=0.078$ respectively). Performance of the cognitive task did not differ significantly between all 3 conditions. In fact, performance tended to be better than that observed when the task was performed alone as a single task in the seated position (e.g., while seated the average number of generated words was 14.5, while during single-legged standing subjects generated 16.7 words, $p= 0.006$).

CONCLUSIONS: The present findings suggest that in young healthy adults, gait, and to some degree standing, have unique attentional demands that are not called in to play, at least to the same degree, in the seated condition. This strengthens the idea that postural control and the maintenance of an upright position are not fully automated and that these motor tasks do utilize cognitive function. In contrast, although the left-right coordination apparently utilizes cognitive resources during walking [1], bicycle pedaling in the seating position does not place an especially high demand on attention. Future studies should further examine how aging and neurological disease modifies these relationships and the specific role played by the maintenance of posture on dual tasking demands.

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Effects of varying cognitive load on young and older healthy adults during fast treadmill walking.

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INTRODUCTION: There is growing evidence of the involvement of attentional resources in gait and posture control in old age [1,2]. Recent evidence suggests that a light cognitive load may improve gait stability whereas a more challenging cognitive load should impair gait, particularly in older adults [3]. However, such a pattern has not yet been examined in terms of muscle activations. To this end, we conducted a dual-task treadmill walking study measuring EMG and stride parameters during single task walking (no-load), and with easy versus difficult cognitive loads. We expected that older adults' walking would be differentially affected by the latter load condition.

METHODS: Young (18-35 yrs; n = 16) and older (60-75 yrs; n = 21) adults first established their walking speed to achieve a moderate self-rated workload. Velocity was then increased by 20% per person. EMG data were collected for eight muscle groups of the dominant leg (VMO, VL, MG, LG, MH, LH, TA, FL). Gait cycles were segmented into single-leg, double-leg, and swing phases. Mean stride time and length were measured using foot switch signals. The cognitive task involved auditory presentation of random two-digit numbers, with the instructions to respond verbally by subtracting 1 or 7 from each number. Vocal reactions times (RT) were collected.

RESULTS: Older adults showed greater mean stride time and shorter stride length than young adults, and these values increased differentially with increasing cognitive load, resulting in significant Age Group x Load interactions for stride time, $F(2, 33) = 4.48$, $p = .019$, $\eta^2 = .214$ and length, $F(2, 33) = 5.40$, $p = .009$, $\eta^2 = .247$. The EMG data were analyzed separately per muscle group and phase of gait. In all eight muscle groups, significant effects of cognitive load were observed (ps < .001), such that differences between no-load and easy load conditions were negligible, whereas EMG values were greater under difficult load. The hamstrings (MH, LH) showed disproportionately greater activity in older adults during double-leg stance and difficult cognitive load: Age Group x Load for MH, $F(2, 34) = 3.12$, $p = .056$, $\eta^2 = .156$; for LH, $F(2, 33) = 7.73$, $p = .002$, $\eta^2 = .319$. On the cognitive task, young and older participants' reaction times were equally affected by the difficulty manipulation, but were not affected by concurrent walking.

CONCLUSIONS: The stride analyses indicate that older adults adopted a slower gait style (increasing stride length and time) with difficult cognitive load, whereas young adults maintained the same gait style. Given that cognitive performance did not suffer with concurrent walking, this shift in gait style may be seen as compensatory to aid in the maintenance of cognitive performance. Contrary to previous findings [3], the current results do not provide evidence of facilitation under easy cognitive conditions, and show increased muscle activity during difficult cognitive load conditions. Notably, the pattern of age interactions is incompatible with a simple interpretation of joint stiffening with age. Further, the comparability of the no-load and easy load conditions suggests that there was a negligible effect of vocalization, and that the major effects are due to the re-allocation of central resources during heavy cognitive load conditions.

ACKNOWLEDGEMENTS: Funded by the Centre for Research in Human Development.

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Synchronisation of walking with a variable metronome

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INTRODUCTION: Walking in time to a metronome improves pathological gait [1,2]. Recently a kinematic analysis has shown that in normal volunteers there is rapid correction in the phasing of walking on the spot to a metronome cue consistent with first-order linear correction [3]. The aim of the present study was to investigate kinetic and kinematic factors underlying synchronisation of walking to an auditory metronome subject to phase shifts.

METHODS: Ethical approval was granted through Institutional procedures at Department level. Five male (age 32.4 ± 6.9 years; height 179.1 ± 4.2 cm; mass 75.9 ± 14.0 kg) and five female (28.6 ± 7.0 years; 165.3 ± 6.7 cm; 62.6 ± 9.7 kg) neurologically normal participants volunteered for this study. The metronome pulses were set to the participant's natural cadence. Five trial conditions were used; no phase shift, +10% phase shift, -10% phase shift, +20% phase shift and -20% phase shift; the order was randomised using a Latin-square crossover design. Ten walking trials in each condition were conducted. A 15-camera Vicon M2 (624) system was used to collect 3-D marker trajectory data sampled at 60 Hz, and were integrated with 3 force plates placed in series. Heel strike was determined through force plate data; when the participant was not over the force plates, the heel strike and toe off timings were determined by correlation of the movement pattern of the ankle marker trajectories recorded during contact with the force plates. Lower-limb kinematics and kinetics were determined using the Plug-in Gait model.

RESULTS: In the trials with no phase shift, heel strike lagged on average 0.02 ± 0.05 seconds behind the leading edge of the metronome pulse. The lengthening phase shifts resulted in the subsequent heel strike occurring either ahead of the metronome pulse, or with a reduced time lag, and the shortening phase shifts resulted in the subsequent heel strike occurring with a greater time lag than the metronome pulse. The correction was not immediate, with 3+ steps required post-phase shift before the heel strike synchronisation with the metronome leading edge was similar to pre-phase shift. The correction was ankle driven; with the ankle moments suggesting initially early stance changes to adjust for the phase change followed by re-synchronisation (see figure 1). On the left the green trace shows the ankle moment at the detection of the phase shift and on the right the green trace shows the same ankle moment at the time of re-synchronisation.

CONCLUSIONS: Advancing or delaying the phase of an auditory metronome during walking results in an asynchrony with gait events which take several subsequent steps to correct. Restoring phase with the metronome beat involves adjusting the sagittal plane ankle moments.

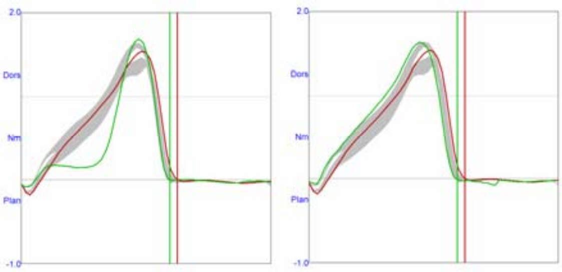

Fig.1 Representative ankle dorsi/ plantarflexion moment data

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P.39

Effects of task-frame orientation and rotation on posture-cognition dual-tasking.

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INTRODUCTION: Interference between posture control and concurrent cognitive tasks is commonly interpreted in terms of competition for information-processing resources, but recent work has started to show that the spatial relationship between the two tasks' reference frames can also affect the ease with which they coexist [1]. Here, we extended this work to the effects of performing a mental navigation task in unperturbed upright stance. The task's overall workspace was either parallel or orthogonal to the posture control workspace (the world-frame), and each navigation step was either statically specified relative to the overall workspace, or dynamically specified relative to the vehicle's local reference frame (Fig 1). We predicted that the orthogonal workspaces configuration and the dynamically specified navigation condition would negatively affect dual-task performance.

METHODS: 36 undergraduates (18-25 yrs) stood in open or closed stance and mentally performed the navigation task by following auditory instructions (e.g., left, right, etc.) after being shown the workspace, the starting position and a target position. At the end of each 4 or 7 step route, they clicked a handheld mouse to indicate whether the target position had been reached. Sway was recorded at 50Hz using an AMTI force plate.

RESULTS: Accuracy in the navigation task dropped 16% for the dynamically specified routes ($p<.05$), and was also lower for longer routes ($p<.05$). Accuracy did not differ with workspace orientation, but RT was significantly greater in the orthogonal condition ($p<.05$). Initial analysis of sway data indicated a significant stance x route length interaction ($p<.05$) on the Ave Vel of CoP (increase in sway for the longer route length was greater in closed stance). The 3-way interaction with static/dynamic directions was also significant for Ave Vel of CoP as well as CoP path length (in open stance, dynamic navigation instructions produced a greater increase in sway as route length increased; in closed stance, increase in sway due to longer route length was the same for static and dynamic navigation.

CONCLUSIONS: Results suggest that mental imagery in a workspace rotated relative to posture control's world-frame, or involving ongoing mental rotation of the task's reference frame, may adversely affect dual-tasking. The study should be extended to test elderly and balance-impaired populations.

ACKNOWLEDGEMENTS: Funded by ESRC grant RES-000-22-2248.

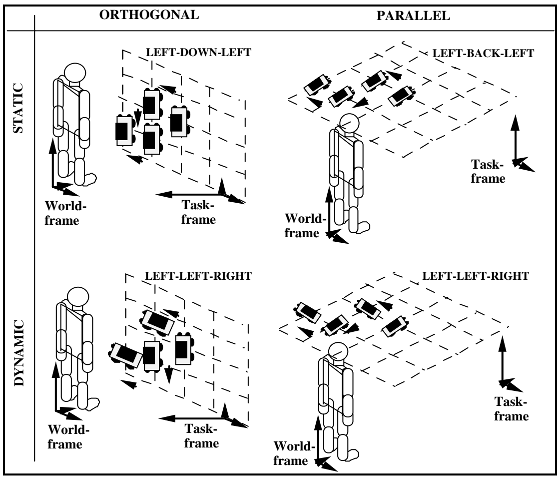

Fig. 1 Cognitive task frames

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The effects of anxiety-related stiffness extend beyond standing balance control

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INTRODUCTION: Standing on elevated surfaces results in standing balance changes characterized by increased frequency and decreased amplitude of the centre of pressure (COP). However, the question of whether this same manipulation affects the control of other joints not involved in standing balance remains to be addressed. This study investigated whether elevated postural threat influences the control of arm posture in the same manner as standing balance. It was hypothesized that similar changes in the frequency and amplitude of displacement would be observed in COP during stance and arm position during pointing.

METHODS: 9 healthy participants, (6 male; aged 21-28yrs) randomly performed three different postural control tasks while standing away from the edge of a 0.75m platform (low threat) and at the edge of a 3.2m platform (high threat). In the first task (static balance task), participants stood as still as possible on a forceplate for 60s with their eyes open and arms at their sides. In the second and third tasks, participants' legs and trunk were supported and their dominant arm braced at the elbow and wrist. During these tasks, participants maintained their arm in a horizontal position as still as possible for 30s while pointing at a target (2x2cm at a 3.87m distance) with visual feedback (arm pointing task) or without visual feedback (static arm task). Root mean square (RMS) amplitude and mean power frequency (MPF) measures were calculated for COP displacements from forceplate recordings (static balance) and arm position recorded using OPTOTRAK markers (static arm and arm pointing). Self-reported measures of perceived anxiety, fear of falling and confidence were recorded for each condition.

RESULTS: Standing in the high threat condition resulted in a significant increase in state anxiety ($p<0.025$). During the static balance task, the MPF of A-P COP increased (% change =14.7%) and the RMS of A-P COP decreased (-15.8%) when standing under conditions of high compared to low postural threat. With respect to arm postural control, increased postural threat resulted in a significant increase in the MPF of arm position in the arm pointing task (6.3%) and in the static arm task (28.0%) in the vertical plane. Likewise, increased postural threat resulted in decreased RMS of arm position in both the arm pointing task (-12.5%) and static arm task (-19.9%) in the vertical plane.

CONCLUSIONS: As shown previously [1], postural threat resulted in a stiffer control of standing balance. Similarly, when performing two postural control tasks not related to the maintenance of standing balance, elevated threat produced an increase in MPF and decrease in RMS of arm position, reflecting stiffer control of the arm. These findings suggest that the effects of anxiety-related stiffness extend beyond standing balance control.

ACKNOWLEDGEMENTS: Supported by NSERC and CIHR.

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Attentional dynamics in gait initiation toward different directions

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INTRODUCTION: Postural adjustments prior to the start of Gait initiation (GI), the transition from quiet stance to steady state gait, are modulated to generate the propulsive forces required to orient the center of mass (COM) displacement toward the desired direction of gait progression [1] as well as to reach the intended gait speed by the end of the first step

[2]. Studies have shown that even well learned activities, such as walking and quiet standing, still require cognitive regulation after years of practice [3-4]. However, it is unclear how attention is being used at each stage of GI as well as which specific actions require the most cognitive processing. Using a classic information processing framework and a dual-task paradigm, we investigated the temporal dynamics of attentional demands during GI toward different directions.

METHODS: Participants were twelve healthy adults aged 20 to 30 with no history of neurological disorders. They started each trial standing on an AMTI force platform embedded into a 5m walkway and at an auditory start signal, initiated gait with their preferred limb at a normal walking speed toward two specific directions: straight ahead (0°) or 40° toward the side of the limb used to take the first step. Heel-off and heel-strike were determined by means of foot-contact switches. The onset of GI was followed by a simple auditory reaction time (RT) task. Subjects were told to respond as fast as possible to the second auditory signal by pushing a handheld button while continuing to initiate gait. RT stimuli were presented randomly at different delays from the onset of GI: 150ms, 300ms, heel-off and heel-strike of the swing limb first and second step. Trials without auditory stimulus were randomly inserted. Direction conditions were blocked and the order alternated between participants. Each participant completed ten trials per dual-task condition for a total of 160 GI trials. In addition to these trials, simple RT control trials performed from a static standing position were assessed at the beginning, midway through and at the end of the experimental session. Differences in RT between those measured in dual-task trials and those in control trials were evaluated. The body's net center of foot pressure and COM were also analysed. Results were submitted to a two-way repeated measures ANOVA, with Direction and RT task as within factors ($\alpha=0.05$).

RESULTS: Overall, mean RTs during GI were larger than those for the static standing task ($\Delta RTs > 54.2ms$, $p<0.000$). A significant interaction between Direction and RT tasks revealed that the postural adjustment prior to the start of GI (until first swing heel-off) demand more attention than the subsequent stages of GI ($p<0.001$) and that the first 300ms of 0° GI required more attention than the first 300ms of 40° GI ($p<0.005$). No significant difference between Direction conditions was observed for Heel-off and heel-strike of the first and second step of the swing limb ($p=0.22$).

DISCUSSION: Our preliminary results suggest that postural adjustments prior to the start of GI are not automatic, and can load the cognitive system. Moreover, attention required to control GI is influenced by the desired direction of gait. Analysis of COP and COM displacement will verify whether attention given to the primary task (GI) is modified by the RT procedure.

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Effects of dual-tasking on gaze behaviour during stair locomotion

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INTRODUCTION: Visual information is required to walk successfully around a variety of environmental contexts. Previous work has highlighted the specific importance of visual information when circumstances demand specific foot placement locations such as walking over stairs. A rationale for a focus on stairs is the link to a high rate of falls and fall–related injuries. Our previous work has revealed specific patterns of gaze behaviour when there were no other visual or cognitive constraints. In the present study, we were interested in understanding the gaze behaviour when individuals were distracted or when gaze behaviour was influenced by another task performed during stair walking. Dual tasking is common in everyday life and the ability to perform a concurrent task while walking on stairs may influence the risk of falls. The aim of this study was to investigate gaze behaviour, specifically gaze fixations, during stair locomotion, while executing tasks that challenge acquisition of visual information and cognitive function.

METHODS: Participants were asked to climb up a regular set of stairs (seven steps) under four conditions: 1) unrestricted walking (UNW); 2) performing a concurrent visual reaction time task (VRT); 3) performing a concurrent auditory reaction time task (ART); and 4) fixating on a target located at the end of the stairway (FIX). The reaction time task consisted of clicking on a wireless mouse in response to either, a letter displayed on a monitor at the end of the stairway (VRT), or a computer tone emitted by speakers (ART). Eye movements were recorded using an eye-tracker and a frame-by-frame analysis of the recordings was conducted to identify gaze location during the walking trials. The number of fixations, mean fixation duration and time in fixation on the steps were calculated.

RESULTS: Participants were able to successfully walk on the stairs while performing the dual task conditions. The dual task conditions did, however, influence gaze and locomotor behaviour. VRT and FIX conditions resulted in fewer fixations and shorter total fixation time on the stairs compared to ART and UNW. Individual fixations lasted, on average, for 209 ± 67ms and did not differ statistically across the experimental conditions. Changes in locomotor strategies to deal with the demands of dual-tasking included reducing gait speed (particularly during ground-stair transition), and the use of handrail.

CONCLUSIONS: When dual tasking, visual information to guide locomotion is minimized to deal with the demands of concurrent visual and cognitive loads implemented by the secondary task. At least in a regular and predictable environment, successful stair walking can still be achieved with minimal locomotor adjustments. The findings of this study agree with the idea that a pre-formed spatial representation of the environment can be used to guide locomotion when online acquisition of visual information is restricted [1].

ACKNOWLEDGEMENTS: CAPES/Brazil, NSERC/ Canada.

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Effects of motor and cognitive dual-task conditions on the modulation of withdrawal reflexes during split-belt walking

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INTRODUCTION: Modulation of the nociceptive withdrawal responses (NWR) was investigated while individuals solved a cognitive task and while adapting to a change in leg coordination during walking.

METHODS: Sixteen healthy volunteers completed 120 stimulation trials on a split-belt treadmill. A brief electrical stimulus was randomly delivered to the arch of the left foot (26.0-47.5mA, 5 x 1ms pulses at 200Hz, at heel-strike or at heel-off) to evoke NWR in the following conditions: 1- when walking at a normal speed of 1m/s, 2- walking at 1m/s and solving a Stroop task (cognitive dual-task), and 3- when walking was perturbed by inducing a sudden unilateral change in speed (a 40% speed increase or decrease) in the right-side limb (coordinative dual-task). Electromyographic (EMG) data from the left Tibialis Anterior (TA), Soleus (SO), Vastus Lateralis (VL) and Biceps Femoris (BF) muscles were collected. Planar joint kinematics of the left hip, knee and ankle, and heel- combined with forefoot-switch data were also recorded. All signals were synchronized and simultaneously collected from 2.5s before and until 2.5s after stimulation at a sampling rate of 2000Hz.

RESULTS: No significant differences in EMG activation were observed between NWRs evoked in either normal walking conditions or when NWRs were elicited during walking and solving the cognitive task. However, unilateral changes in speed facilitated NWRs in the extensors (VL and SO) but not in the flexors (TA and BF). This was particularly observed during adaption to speed changes from a symmetric walking mode to a slow asymmetric mode from 1m/s to 0.6m/s but not from 1.4m/s to 1m/s. On the other hand, speed increases did not cause any effects. NWR onsets in flexor and extensor muscles were not affected by the experimental conditions. Kinematic patterns observed for the ankle (i.e., angular joint motion before and after stimulation) supported the electrophysiological evidence.

CONCLUSIONS: NWR timing was not affected by changing experimental conditions but NWR amplitudes did. If the effect on the NWR were related to biomechanical adjustments one would expect to see a change in the EMG timing as well as in the temporal evolution of the angular path (i.e., the angular speed). This was not the case. Furthermore, stimulation was provided after subjects regained balance (>3sec after the change in speed), during the adaption period to the new asymmetric walking condition. Finally, if only balance adjustments determined the EMG activity, one would expect such effect for any speed change. However, the effect was observed mainly when slowing down (and never when increasing speeds), and it was significantly greater when subjects adapted to changes from normal speed (1m/s) to slow walking speed (0.6m/s). In conclusion, it is unlikely that the facilitatory effects on NWR observed during asymmetric walking are confounded with the adjustments to the biomechanical perturbation, i.e. the attempt to regain balance. These effects seem to be associated instead with NWR modulation that expresses in changes of the reflex amplitude. Such modulation may depend on the type of attention required for performing a secondary-task: attention devoted to solving a cognitive task caused no changes in the withdrawal response, but attention devoted to solving a coordinative task brought about NWR facilitation, particularly when adapting from normal speed to a slower asymmetric walking speed. It may be argued that spinal and supraspinal levels interact differently depending on the dual-task condition and on the direction (increase or decrease) and the magnitude of the speed constraint (slower or faster than normal).

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Multiple dimensions of balance are adversely affected in older adults with Fibromyalgia

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INTRODUCTION: Individuals diagnosed with Fibromyalgia (FM), a musculoskeletal pain disorder that is characterized by widespread bodily pain and tenderness of unknown origin, frequently report symptoms of imbalance, tingling and numbness in the extremities, painful neuropathies, and dizziness when surveyed [1]. These symptoms, coupled with the aging process, are likely to result in higher levels of sedentary behaviour, physical de conditioning, and heightened risk for falls due to impairments. To date, no studies have attempted to identify how these symptoms impact the different dimensions of balance and mobility in older adults who are aging with the disease.

METHODS: Multiple dimensions of balance were assessed in a group of 69 older adults (M = 60, SD=7.62) with a confirmed diagnosis of FM (OAFM) and a group of 75 healthy, older adults (OAH) (M=68, SD=8.77) as part of a comprehensive evaluation of cognition and physical function. Specifically, four dimensions of balance were evaluated by grouping individual test items on the Fullerton Advanced Balance (FAB) scale [2] as follows: Static balance (items 2 & 6), dynamic balance (items 3, 4, 5 & 8), sensory reception and integration (items 1, 7, & 9), and reactive postural control (item 10). This scale, which was originally designed to evaluate the multiple dimensions of balance in independently functioning older adults, has recently been shown to be a reliable measure of balance when administered to individuals with FM [3]. Group differences were investigated using a Multiple Analysis of Covariance (MANCOVA) with age as the covariate.

RESULTS: A significant group difference was evident for the combination of dependent variables (Pillai's F (4, 138) = 6.636, $p < 0.001$) analyzed. Follow-up univariate analyses further indicated that the groups differed significantly in the dimensions of static balance (F (1, 141) = 15.228, $p < 0.001$), dynamic balance (F (1, 141) = 19.279, $p < 0.001$), and sensory reception and integration (F (1, 141) = 13.687, $p < 0.001$) with the OAFM group scoring significantly lower on each of these balance dimensions. No significant group difference was evident for the dimension of reactive postural control (F (1, 141) = 2.265, $p = 0.135$).

CONCLUSIONS: The results of this study confirm previously published self-report findings and suggest that the balance problems identified result from impairments in both the sensory and motor system. Further studies are needed to elucidate the specific cause(s) of the balance problems identified and the types of intervention strategies that are effective in addressing the specific problems identified.

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Evaluation of the posture of patients suffering from Fibromyalgia

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INTRODUCTION: Fibromyalgia is a syndrome difficult to diagnose. The American College of Rheumatology diagnoses fibromyalgia to patients who have been suffering for over 3 months, indirectly, without clinical or laboratory abnormalities that could explain it. Verification of Yunus painful points less than 4 kg with a compression dynamometer with the pulp of the thumb. This study is trying to determine if the orthostatic posture in fibromyalgia is superimposed on that of the witness in three dimensions.

METHODS: A compression dynamometer was used for looking the presence of more than 11 Yunus's points. 219 patient(s) referred for fibromyalgia from 2006 to 2008 were given this test and were subject to an assessment of their posture in 3D in one shot (stereoscopic photography): face, profile and transverse with a SAM 3D section. Patients were invited to watch a target at 5 meters and then mark time a few seconds to find a balance as comfortable as possible. The analysis was made to a vertical virtual line through the middle of the feet.

RESULTS: Group 1 - 106/219 subjects ≥11points of Yunus have the criteria of fibromyalgia.
Group 2 - 113/219 subjects <11 points of Yunus do not have the criteria of fibromyalgia.
60% of group 1 (64/106), the fibromyalgia group decline their heads and shoulders compared with the witness. The decline is on average 55 mm in the head and 33 mm at the shoulders. The average decline was 1.7 times the standard deviation. There was no difference for the pelvis. 10% of group 2 (11/113), which does not meet the criteria of the fibromyalgia decline the head and shoulders in 10% of cases. The two groups are different 1 degree of freedom Chi2 = 32.94

CONCLUSIONS: The three dimensions posturography is completing the screening of fibromyalgia. The backward movement of the upper trunk can compensate for a large abdomen. The backward movement of the upper trunk may be the consequence of a pelvic retroversion or abnormal biomechanics. Emotional patients adapt their posture to a backward movement of the head and shoulders thus avoiding painful points probably at the beginning. Pr Henri Laborit showed in 1973 that emotions are accompanied by a modulation of the tonus.

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Measurement of cognitive and emotional influences in relation to Fibromyalgia.

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INTRODUCTION: Fibromyalgia is a disease affecting more than 2.5% of the population, figuring in the International Classification of Diseases (ICD) of the WHO both as a disease of the locomotive apparatus and as a psychiatric (somatoform) disorder [1]. The inter-relationships between somatoform disorders of the post-traumatic variety and fibromalgic syndromes have already been established. The old diagnostic method based only on determination of trigger points would today appear to have been rejected, even by its author, in favour of metrological methods [2]. As a consequence, we wished to discover whether a posturographic study of fibromyalgic patients could help with the diagnosis of fibromyalgic syndromes.

METHODS: We carried out a systematic postural study of a sample of 47 patients already diagnosed as fibromalgic. We then looked for posturographic criteria of anxiety and post-traumatic stress disorders on the SKG surfaces [3]. We then compared the sample of fibromyalgic subjects with a sample of 47 subjects presumed to be unaffected.

RESULTS: The results of the chi-square test (see Table 1) indicate a significant increase (approximately 50%) in posturographical criteria in fibromyalgic subjects in the results corresponding to the usual expression of post-traumatic stress disorder whereas in the unaffected subjects this proportion is not significant, being of the order of 10% [3].

CONCLUSION: Based on the posturographical results expressed here, it would appear to be appropriate to measure fibromyalgic subjects on a force platform in order to determine the existence of somatoform disorders. This method also has the advantage of enabling an orthotic postural treatment to be given, as is already indicated for post-traumatic stress disorder, in order to reduce manifestations of anxiety.

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Samples	> at 210 mm^2 EO and 600 mm^2 EC	SKG normal	**Total**
47 fibromalgic subjects	**23**	24	**47**
47 unaffected subjects	03	**44**	**47**
Total: 94	**26**	**68**	**94**

Table 1

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Anticipation of the effects of stress at work on the basis of posturographical parameters

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INTRODUCTION: Harmful stress (distress) is commonly described as the state in which subjects become unable to meet the demands put upon them [1, 2] The state of stress may also be expressed as a succession of fears. As postural markers of fear have already been determined [3] we propose the hypothesis of the readability and, as a consequence, the anticipation of the pathological effects of stress by means of a posturographical examination.

METHODS: We studied, on a force platform, a sample P of 21 female subjects aged between 30 and 45 years old working in stressful occupations, and having already consulted after the manifestation of intense stress at work. We compared these stabilometric results with those of a sample N of 21 subjects of the same sex and age range working in sectors recognized as being less stressful [4].

Sample P measured Eyes Closed	Surfaces	Speed	Sample P measured Eyes Closed
Sample of 21 subjects	478mm^2	11.2	Sample of 21 subjects
Differences in respect of Norms 85	+ 460%	Not Defined N 85	Differences in respect of Norms 85

Sample N measured Eyes Closed	Surfaces	Speed	Sample N measured Eyes Closed
Sample of 21 subjects	254mm^2	6.9	Sample of 21 subjects

Table 1

RESULTS: The results are in Table 1.

CONCLUSIONS: The stabilometric results of the sample composed of subjects not affected by stress (N) and working in non-stressful occupations are normal. The results of the sample composed of subjects affected by stress (P) and working in occupations recognized as stressful show certain anomalies, particularly in terms of SKG surfaces and speed. These discoveries would appear to show that it is possible to quantify the importance of the effects of stress at work by measuring the individuals on a force platform. SKG surfaces and speed may be considered as potential markers of the readability of the effects of stress in terms of the postural regulation system. This approach would appear to be capable of anticipating the effects of stress and of anticipating the pathological consequences, which are sometimes severe

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P.48

Postural sway in dual task conditions

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INTRODUCTION: The paradigm of dual task differs among authors. During quiet stance on the force platforme subjects performed varity of different secondary tasks such as search test, calculation tasks and Stroop test. The results of those studies are conflicting, some reported an increase of sway parameters others did not find any differences while the third line of results reported reduction in the sway parameters in dual task conditions. The purpose of present study was two-fold: to investigate postural sway in dual task conditions during narow stance, and to investigate the time dependency of sway parameters.

METHODS: Forty-one young subjects (22.6 ± 2.5 years) participated in this study. A force platform (Kistler 9286AA) was used for recordings during 60 seconds of quiet barefoot standing with feet close together. Four consecutive tests were performed: (1) eyes opened and looking into the dot (EO), (2) eyes closed (EC), (3) first dual task (DT1), (4) second dual task (DT 2). Modified Stroop colour test was used as a second cognitive task DT 1: colour words were projected on the screen, subjects were asked to read the word as it was written, DT 2: the subjects were asked to name the colour of the word and not the word itself.

RESULTS: The medio-lateral path, antero-posterior path, total path (cm), sway area (cm^2) and the index of sudden excursions (ISE) [1,2] were calculated. Postural sway significantly differed between the four tests. Compared to eyes opened condition sway was significantly larger during EC and DT 2 ($p<0.001$) in the dual task experiment with conflicting attentional demands. However during DT 1 simple reading of the printed words alone did not increase sway parameters except for the ISE [1,2]. In the dual task conditions the habituation to experimental conditions could be expected. Therefore we analyzed separately each 20 seconds of the one minute measurement interval. The results showed that in the test with EC, DT 1 and DT 2, parameters of postural sway gradually decreased with time: initial 20 seconds towards last 20 seconds (Fig. 1). The difference was statistically significant at $p < 0.05$ level or less. The results of the dual task are at the last time interval almost the same as in the single task conditions (Fig. 1).

CONCLUSION: The influence of dual task on sway parameters depend on the nature of the secondary task. The majority of differences occurred in the first 20 seconds of the measurement interval. The most sensitive parameter was ISE which has discriminative potential in different cognitive conditions as well as in age groups and different sensory conditions [1].

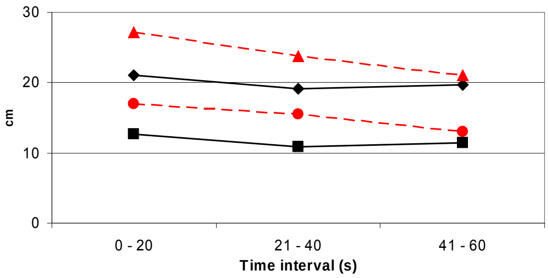

Fig. 1 Time dependency of sway parameters: total path (diamond), and antero-posterior path (square) in single task eyes opened and dual task conditions (triangle and circle

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Step length adjustments during the approach of a raised surface

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Introduction: Fall accidents amongst elderly are often associated with difficult walking conditions [1]. For an elderly person this may imply the task of climbing a curb after crossing a street. In relation to this task the motor planning with respect to adjustment of the steps is critical [2]. In order to gain insight in these aspects this study investigated whether the gait adjustments in response to the negotiation of a raised surface are different between elderly and young people.

Methods: Fourteen young subjects and eleven community-dwelling healthy elderly participated in the study. Gait characteristics were evaluated during the approach of a 15 cm high platform which had to be negotiated. In a second set of trials the participants were additionally challenged by an arithmetic dual task. Gait parameters were measured by an electronic walking mat.

Results: In both groups the gait pattern was modified as to adjust for the optimal foot placement of the last step in relation to the edge of the platform. During the approach of the raised surface the young participants had a tendency to increase their step length and step velocity while the elderly shortened the step length and slowed the velocity.

Major step length adjustments began four steps before ascending the platform in the group of young participants (figure 1). The elderly began making major adjustments only three steps before the ascendance. This age dependent difference could not be observed during dual task condition.

Conclusions: When approaching a raised surface elderly people have a tendency to walk slower and make the necessary gait adjustments at a later stage than young. This strategy may imply a loss of inertia and influence the climb onto the raised surface.

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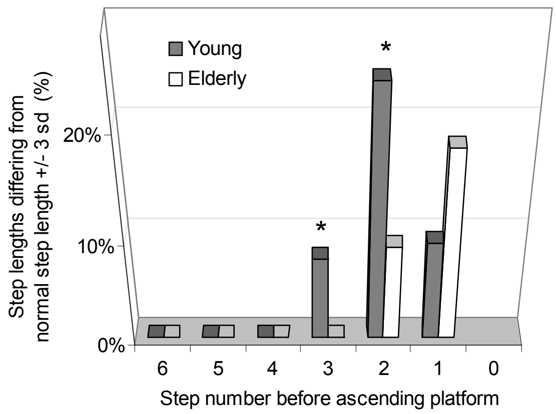

Fig.1 Age related differences in the frequencies of major step length adjustments during the approach of a raised surface. * $p<0.05$

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P.50

Strategies to circumvent suddenly appearing obstacles in young and older adults

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Introduction: Reduced ability to circumvent an obstacle, which is noticed only shortly before collision, could be a cause of falls and injury, especially in older adults. Previous studies on obstacle circumvention [1,2] have shown age-related velocity reduction when circumventing an obstacle that was visible well in advance. When externally perturbed in the medio-lateral direction during stance, cross-over stepping and side stepping strategies have been observed in both young and older adults [3,4], while during walking in place, both young and older adults prefer side stepping, although older adults showed more steps and interlimb collisions [5]. The aim of this study was to test for differences in strategies and their characteristics between young and older adults in circumventing a suddenly appearing obstacle during gait under critical time conditions.

METHODS: Twenty-one young (24±3 years) and ten older (69±4 years) adults walked down a 12-m platform at 1.2 m/s, while in 16 out of 96 trials an obstacle (horizontal poles at ankle and shoulder height) appeared halfway, blocking their passage. Obstacle appearance was timed based on on-line kinematic data, around right heel strike in front of the obstacle, to provide Available Response Times (ARTs) of 850, 1000 or 1150 ms. Subjects were asked to circumvent the obstacle to the right and continue walking. Foot position, ground reaction forces and muscle activity were measured.

RESULTS: In both age groups, circumvention strategies could be classified as either side stepping or cross-over stepping. Side stepping was characterized by a quick and shortened left foot placement, followed by a step to the right by the right leg. Cross-over stepping was characterized by crossing the left foot in front of the right foot to circumvent the obstacle. Strategy choice was significantly affected by ART and age; older adults preferred the side step strategy, especially when ART was shorter (Figure 1). Backward and sideward peak ground reaction forces, resulting in forward velocity reduction and sideward velocity increase, were more pronounced for side stepping than for cross-over stepping.

CONCLUSIONS: Older adults perform similar strategies as young adults to circumvent a suddenly appearing obstacle during gait, with a stronger preference for side stepping for shorter ART. This strategy appears a more stable strategy although it is more demanding in terms of force generation.

Fig.1 Strategy choice over age and ART

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Effects of pilates training on shoulder and upper body posture and movement

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INTRODUCTION: Upper spine posture and neck-shoulder biomechanics are important factors of neck-shoulder pain. Recent work has shown that misalignment of the upper spine brings the scapula in a more anterior tilted and protracted position, which restricts the range of motion (ROM) of the shoulder and decreases the subacromial space, potentially leading to shoulder impingement [1]. The Pilates method is a physical training approach that focuses on posture, core control, flexibility and segmental alignment, through posture and movement exercises [2]. Pilates training is practiced around the world; however only few studies have investigated its effects on body biomechanics and none have specifically investigated its effects on upper spine and neck-shoulder biomechanics [3].

METHODS: 19 healthy subjects (9 control, 10 experimental) participated in this study. All subjects performed the assessment protocol twice, 12 weeks apart. In it, we assessed three-dimensional kinematics of the shoulder and spine (VICON-Peak©) and activity of 16 muscles (Noraxon©) while seated subjects performed maximal shoulder flexion trials. Abdominal strength and static postural alignment were also measured. Subjects from the experimental group were trained individually following the Pilates method twice a week (24 sessions). ANOVAs time x group were performed to assess the effects of Pilates training on the various parameters.

RESULTS: There were no main or interaction effects on shoulder peak angles during the shoulder flexion task. However, there were significant group x time interaction effects for scapular two-dimensional displacement, upper thorax extension range, and lumbar lateral flexion range during the shoulder flexion task, with the Pilates group showing comparatively smaller scapula and upper trunk displacements after the training and the control group showing comparatively greater lumbar displacements in the post-test. There were also interaction effects for the contralateral rhomboid and ipsilateral lumbar erector spinae EMG amplitude throughout the shoulder flexion task, with respectively higher and lower activity after Pilates training in the experimental group, as well as interaction effects for ipsilateral cervical erector spinae during the first 90° of the shoulder flexion task, with increased activity after Pilates training. Finally, abdominal strength and thoracic kyphosis showed interaction effects, with significantly increased abdominal strength and decreased thoracic kyphosis with time in the Pilates group only.

CONCLUSIONS: A 12-week Pilates program was effective in improving core strength, upper spine alignment and dissociation between arm, scapula and trunk motions during a shoulder flexion task and in affecting activity across muscles of the shoulder and trunk. As deficits in neck-shoulder biomechanics have previously been associated with symptoms in the neck-shoulder region [4], our results support the use of Pilates in the prevention of neck-shoulder disorders.

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P.52

Sensory re-weighting induced by challenging balance exercises

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INTRODUCTION: The purpose of this study was to investigate the effects of challenging balance exercises on the ability of the central nerve system (CNS) to re-weight sensory cues. The balance exercises included a gym ball exercise and a balance board exercise. The gym ball exercise requires participants to maintain balance on the ball (φ 75 cm) in a sitting or crawling posture. By contrast, in the balance board exercise, participants try to keep an up-right stance on unstable boards. We hypothesized that somatosensory cues from the legs and feet became less reliable after the exercises (therefore less weighted) for participants using the gym ball and more reliable (therefore more weighted) for participants using the balance board. Properties of adaptation were also discussed.

METHODS: Twelve healthy young males participated in this study. The participants were divided equally into two groups. One of the groups participated in the gym ball exercise (G group), and the other participated in the balance board exercise (B group). The center of pressure (COP) was measured by a force plate prior and posterior to the balance exercise. Barefooted, eye-closed participants stood directly on top of the force plate (firm condition) and on a foam pad on top of the force plate (foam condition) for 35 s. In the G group, participants tried to sit on the ball without contacting the floor with their feet for 3 min. After 2 min rest, they tried to ride on the ball by crawling for 3 min. In the B group, participants tried to stand as steadily as possible on two types of balance board. In the first exercise, there was a narrow support point under the center of the board and the board was unstable in all directions. In the second exercise, there was a wooden bar under the board and the bar was free-rolling in the medio-lateral direction. Both board exercises lasted for 3 min and there was a 2-min rest between the exercises. Prior to the post-exercise measurements, the participants were given as much rest as desired, so fatigue was not an issue. The COP sway area (area of 95% confidence ellipse determined by COP trajectory) and COP sway velocity were calculated as dependant variables. Repeated measure ANOVAs were conducted for each variable in 2 groups × 2 conditions × 2 measurements.

RESULTS: In the foam condition, the COP sway area and velocity were always larger than those in the firm condition. In the G group, the foam condition post-exercise sway velocity was significantly less than the pre-exercise sway velocity. By contrast, the foam condition post-exercise sway velocity was significantly greater than the pre-exercise sway velocity in the B group.

CONCLUSIONS: As we expected, after the gym ball exercise, the destabilizing effect of the foam surface decreased, and after the balance board exercise, the destabilizing effect increased. These results suggest that challenging balance exercises require participants to up-weight sensory cues that are more useful for achieving tasks and to down-weight cues that are less useful. These results also suggest that the effects of exercises retain for several minutes. A challenging environment may force participants to adapt rapidly, but in an unchallenging environment, adaptation need no longer be rapid. It may be reasonable to consider the CNS to have such asymmetry in postural control to reduce the risk of falling. Interestingly, results in the G group indicated that sensory re-weighting induced by exercise (sitting and crawling on the ball) could be transferred to another posture (up-right stance). That is, the CNS may have the ability to transfer the adaptive effects on multisensory integration from one posture to another posture.

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Ministry of Education, Culture, Sports, Science and Technology.

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Effects of dual task balance training in healthy elderly people

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INTRODUCTION: Many studies have reported that dual-task performance while standing is related to falls in elderly people. Therefore, for preventing falls in elderly people, it is important to train them so as to improve their dual task performance. However, the effects of such dual task training have not been well documented. Hence, in this study, we investigated the effects of dual-task balance training on standing posture control under a dual-task condition in healthy elderly people.

METHODS: The study population comprised 41 healthy elderly people (mean age: 72.3 years) who gave their written informed consent prior to the commencement of the study. The participants were randomly assigned to a single- or a dual task balance training group (ST group: n = 21, DT group: n = 20). The subjects in the ST group performed strength and balance exercises, while those in the DT group performed visual and auditory cognitive tasks simultaneously with strength and balance exercises. The frequency of training in both the groups was 2 times a week for 3 months. The length of the trajectory of centre of pressure was measured before and after the training under 3 conditions: when the subjects stood with their eyes open, stood with their eyes closed and performed the stroop task. The record of stroop task (RST) was also measured. Statistical analyses were performed for inter-group and intra-group comparisons.

RESULTS: There were no significant differences for any of the outcome measures between the groups before the training. However, the RST was significantly greater in the DT group than in the ST group after the training ($p < 0.05$). In the DT group, the RST before the training was significantly greater than that after the training ($p < 0.01$).

CONCLUSIONS: These results suggest that dual task balance training is more effective in improving the dual task performance while standing in healthy elderly people.

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Muscle specific adaptation to vibration-induced postural disturbance

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INTRODUCTION: In response to repetitive proprioceptive disturbances (muscle vibration) applied to postural muscles, human standing subjects have been shown to adapt, i.e, the evoked response decreased in amplitude within the first few trials [1-3]. The present experiment investigated whether adaptation to proprioceptive disturbance (vibration at 90 Hz, 5 s) is muscle specific or is transferred to the antagonist muscle.

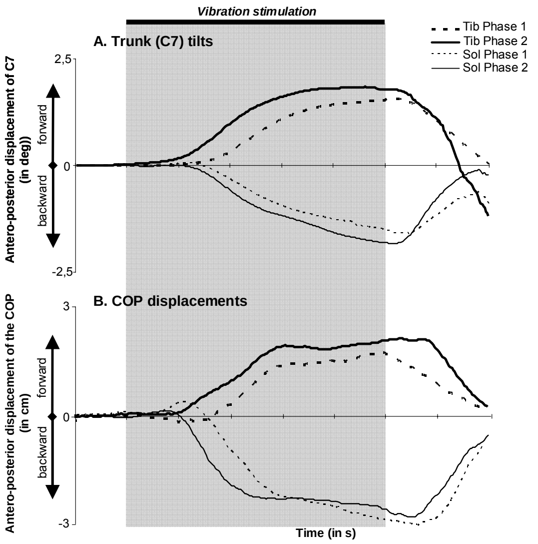

Fig.1 Mean trunk tilts (A.) and COP displacements (B.) for the two vibration sites condition in phase 1 and in phase 2

METHODS: 40 participants stood upright in complete darkness. One half of the participants practiced 15 tibialis vibrations followed by 15 soleus vibrations (TIB-SOL sequence), while the other half practiced the opposite sequence (15 soleus vibrations followed by 15 tibialis vibrations, SOL-TIB sequence). Antero-posterior trunk displacements were measured at the level of C7. Centre of pressure (COP) as well as EMG activity of the tibialis anterior and gastrocnemius lateralis were additionally measured in 16 participants.

RESULTS: Results showed that participants adapted to the vibration of either soleus or tibialis muscles within the first 2-3 trials. However, this adaptation-habituation was not transferred to the antagonist muscle. In contrast, mean amplitude and velocity of the postural displacements were even more important when the antagonist muscle was previously stimulated, i.e. in phase 2 compared to the phase 1 (Fig 1).

CONCLUSIONS: The fact that adaptation did not generalise to the antagonist muscle attests of its specificity. Adaptation to postural disturbance is usually interpreted in terms of sensory re-weighting

[3,4]. Our results suggest that if a down-weighting of the proprioceptive channel can be involved in the present postural adaptation, it appears to be selective and restricted to the muscle, or chain of muscles, from which the unreliable signal is originating.

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P.55

Adaptations to repeated slips during forward and backward walking

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INTRODUCTION: Forward walking is a familiar task predominantly performed in a pre-programmed manner. On the other hand, backward walking, often included in clinical and rehabilitation training regimen, is considered a relatively novel motor task requiring a reorganization of central nervous programs involved in gait. One critical requirement for maintaining balance in either direction during gait is the ability to generate proactive postural adjustments in the face of external perturbations. These adjustments might include alterations in the body's center of mass (COM) state, i.e. a repositioning of the COM with respect to the base of support or modifying the COM velocity [1-2]. The purpose of this study was to investigate anticipatory postural strategies when repeatedly exposed to a slipping perturbation during forward and backward walking.

METHODS: Seven subjects, 5 young (3 M, 2F, 29±6 years) and 2 older (1M, 1F, 73±1 years), were recruited for participation. Subjects were first asked to walk on known dry floors to retrieve baseline forward and backward gait characteristics. In each walking direction, presented in a random order, the slipping protocol included 2 experimental conditions: (1) unexpected slip (subject unaware of the slippery condition and expecting a dry condition) (2) 5 repeated slips (subject aware of the slippery condition). Ground reaction forces and whole body motion were collected and the slip was induced at foot contact with a glycerol solution. Anterior-posterior (AP) COM position with respect to the ankle at foot contact was the dependent variable regressed on exposure trial (unexpected/repeated slip1/repeated slip 5) and subject as a random effect. This analysis was conducted within each walking direction with statistical significance set to $\alpha = .05$.

RESULTS: The exposure number effect on the AP COM position with respect to the ankle was statistically significant only in the forward walking direction ($p<.05$, Fig.1). Specifically, the AP distance between the COM and the ankle decreased by an average of 21% in the repeated slip trials compared to the unexpected slip trial. No statistically significant adaptations were evident between the first and fifth repeated slip trials.

CONCLUSIONS: The findings of this study suggest that postural adaptations in the face of known perturbations may be more challenging to achieve when the motor task is novel. Further results describing AP COM velocity will be presented at the conference.

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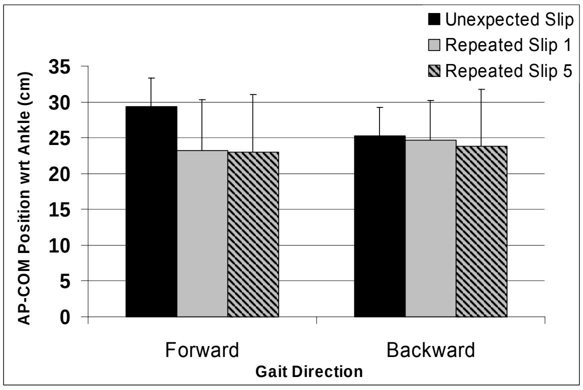

Fig.1 AP-COM changes in the forward direction

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Gender differences in postural control in individuals with visual impairments

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INTRODUCTION: The ability of an individual with a visual impairment to maintain standing balance is compromised due to reduced visual feedback [1]. Loss of vision also negatively impacts mobility, and is associated with an increased Basal Metabolic Indices (BMI), decreased lower body strength and reduced overall health [2]. The relative contribution that each of these variables has on postural stability is still unclear. Therefore, there is a need to explore these factors to determine their contribution to decreased postural stability among individuals with profound vision loss.

METHODS: Sixty-five adults (20-65 years) were divided into three categories (low vision, medium vision, and sighted), using the International Blind Sport Association (IBSA) classification system [3]. A multiple regression analysis was performed examining the relationships between age, gender, quadriceps/hamstring strength (isokinetic), somatosensation and vestibular function to the composite score from a NeuroCom Sensory Organization Test (SOT).

RESULTS: Results indicated that the two contributors to decreased postural stability were visual status (Beta = -.318) and gender (Beta = -.299). The multiple regression analysis found no significant relationships between postural stability and the participants' BMI, quadriceps/hamstring strength or age. The multiple regression analysis found a significant relationship between the predictors (visual status and gender) on postural control (SOT composite score) ($F_{(2, 64)} = 8.33$, $p = .001$). The effect of visual status on postural control resulted in a change of -2.76 ± .92 SOT composite units (t = -3.00, p = .004) for each unit change of visual status classification. The impact of gender on postural stability resulted in a change of -5.95 ± 2.45 SOT composite units (t = -2.43, p = .018) associated with being female. The final model consisting of visual status and gender resulted in an r = .50 (SEE = 9.39); accounting for 25.1 % of the total variance. The mean SOT composite score was 80.7 ± 5.40 and 73.9 ± 14.9 for men and women, respectively. The only significant within group difference on SOT composite score occurred in the participants that were in the low vision category (IBSA classification) ($F_{(1,13)} = 7.46$, $p = .018$), with men scoring higher than women. Visual status had an r correlation of -.339 (p = .006) to the overall SOT composite score; however the only condition with a significant relationship between visual status and postural instability was the visually impaired groups performance on condition 4 (r = -.545, p<.001) of the NeuroCom SOT. Between group differences for condition 4 resulted in an $F_{(2, 64)} = 4.02$, $p = .023$. The mean value for the sighted group for condition 4 was 84.5 ± 7.39, medium group was 73.4 ± 12.7, and low group was 63.6 ± 17.1. Isokinetic strength testing yielded no differences between groups (p > .05) and when peak torque was normalized for body weight, no gender differences (p > .05) were present.

CONCLUSIONS: The results from this study provide preliminary evidence to show that postural stability is disproportionately reduced in women with vision loss. Based on the data analyses, while decreased visual status apparently contributes to postural instability, the predominant contributing factor to this instability is reduced visual input (condition 4), which primarily affects postural control in women. This result is noteworthy, because by identifying adult women with vision loss as being disproportionately at risk for decreasing postural stability, fall prevention programs can target women with declining vision loss.

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P.57

The immediate effect of moderate physical activity on the postural stability of older people.

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INTRODUCTION: Understanding the predisposing factors for older people falling is imperative as falls lead to considerable medical and societal costs and loss of independence and quality of life for many. It is particularly important to understand more about the many possible intrinsic and extrinsic reasons why older people sometimes fail to maintain their postural stability and fall. Older people are increasingly being encouraged to maintain or increase their daily physical activity levels. Healthy older people have been shown to have altered postural stability following high intensity physical activity [1-2], however it is not known whether postural stability is compromised during everyday levels of activity. The aim of this investigation was to determine whether postural stability in standing, during a dynamic activity and following an unexpected perturbation, was detrimentally affected by moderate intensity mobility activity.

METHODS: Three investigations were undertaken, each comparing postural stability pre and post a moderate intensity mobility activity. The first recorded centre of pressure (COP) displacement during quiet standing with feet together. The second recorded forces and postural EMG activity during a rapid forward step-up task. The final study recorded postural response strategies to a lateral waist-pull perturbation large enough to elicit a step response. The first two compared healthy young adults with healthy older and balance-impaired older adults, whilst the final study compared health young and old. The mobility activity involved a series of tasks carried out continuously for 14 minutes, self-paced at moderate intensity. Tasks included walking, step-ups, mini-lunges and avoiding obstacles.

RESULTS: In quiet standing, all groups demonstrated larger COP displacement in the mediolateral direction following the physical activity. For the step-up task, all groups showed small improvements in the timing of the duration of the weight-shift phase, lateral COP displacement during weight-shift and stance leg hip abductor muscle onset times, but also a shift in COP position towards the stance side prior to the step for the after activity trials. Finally, for the lateral perturbation task, the older participants had increased frequency of cross-over steps after the activity, which are thought to be a less optimal response than the faster and more stable single outward steps. However, those who did perform a single outward step to recover balance following the physical activity performed them as well as they did before.

CONCLUSIONS: Small changes to postural stability during standing and voluntary stepping were found following moderate intensity physical activity, however these changes were thought to be unlikely to lead to a greater risk of falling. An increased rate of using a cross-over strategy to regain balance after perturbation may increase falls risk. We speculate that the changes found may be due to the impact of subjective feelings of tiredness impacting on attentional resources required for postural control.

ACKNOWLEDGEMENTS: PhD scholarship funded by Australian Federation of University Women – Queensland Branch.

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The influence of the action observation in learning of the standing balance performance

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INTRODUCTION: Performing a motor task or observing other individual performing the same motor actions activates mirror neurons in the prefrontal and parietal cortex of monkeys. In humans, action observation results in increased cortical excitability of the primary motor cortex and has been implicated in motor learning. In the previous researches, the motor task of the upper limbs has been used, but the tasks of the standing position and the systemic movement such as postural balance have not been used. The purpose of this research is to investigate the brain activities while others' movement is being observed by using the game.

METHODS: Seven university students participated in this research. WiiFit known as a video game was used for the movement task. A participant had the functional near infrared spectroscopy (fNIRS) of the cerebrum in the terms of game observation and the terms of game practice. A participant observed the game execution scene of the skilled person from the back in terms of game observation. As for terms of game practice, a participant actually performed a similar observed game. A measurement outcome was oxy-hemoglobin (oxy-Hb) concentration.

RESULTS: An oxy-Hb concentration during the action observation showed significant increase in the premotor cortex. On the other hand, there was no change in the oxy-Hb with primary motor cortex. As for the oxy-Hb concentration when a movement was being carried out, even a premotor cortex recognized increase as well as the primary motor cortex.

CONCLUSIONS: Observing others' movement activated premotor cortex in the cerebral of the observer. That reflects the mental simulation of the movement performance. Action observation may be a beneficial application for motor learning strategy.

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Learning effect in a dynamic balance control

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INTRODUCTION: Quiet stance requires a constant muscle tone, which changes to a different muscle activation pattern when subjects balance on a continuously oscillating platform. This muscle activity serves to control the centre of foot pressure (CFP) to keep the body stable in space and the centre of mass (CoM) in a safe place above the support surface. Several studies have been performed to investigate this dynamic balancing behaviour [1-4], nevertheless it is still unclear if the successive repetition of this task can optimize the strategy of the equilibrium control. Is muscle activity larger during the first trails to become progressively less important with trial repetition? Does the amplitude of the CFP and of CoM oscillations diminish with the repetition of the trials? Does the optimization of the balance strategy depend on the sensory information available?

METHODS: Ten subjects riding a platform continuously moving in the antero-posterior direction at two different oscillation frequencies (0.6 Hz and 0.2 Hz) with the same amplitude of oscillation (10 cm) under two different visual conditions (eyes closed (EC) and eyes open (EO)). Each subject performed three trials for each frequency and visual condition. Each trial lasted 4 minutes. EMG activity of the tibialis (TA) and soleus (SOL) muscles was recorded by a Tele-EMG and the area of the filtered and rectified signals was computed. The position of 20 reflective markers positioned on the body landmarks were acquired by means an optoeletronic device in order to compute the oscillations of CoM. The oscillations of the CFP were measured by sensorized insoles. For each trial, the mean amplitude (peak-to-peak (PP)) of the oscillation signals was compute.

RESULTS: The EMG area of the TA and of the Sol decreased within the three trials carried out by each subject. This effect was evident when the trial condition was more challenging (0.6 Hz with EC). At a 0.6 Hz with EC the mean area of the TA of the first trial as well as of the Sol were significantly higher with respect to that of the second and of the third trials and the area of the second trial were significantly higher with respect to that of the third trial. Similar results but only for the area of the TA were obtained for the same platform frequency with EO and for 0.2 Hz platform oscillation with EC. No significant differences were found between the three trials with EO at 0.2 Hz for the TA, and with EO at 0.2 and 0.6 Hz for the Sol. Furthermore, the area of the Sol did no significantly change among the three trials at 0.2 Hz with EC. The mean PP amplitude of the CoM oscillation was similar in all the three trials performed in each visual condition and in each frequency condition. On the contrary the mean PP amplitude of the CFP showed significant differences within trials. At a 0.6 Hz with EC as well as with EO the PP index of the first trial was significantly larger than that of the second and the third trial and that of the second trial was greater than that of the third trial. At 0.2 Hz with EC the PP of first trial was significantly larger than that of the second and the third trial. On the contrary the amplitude of the PP of the second trial was comparable to that of the third trial. No differences within trials were found at 0.2 Hz with EO.

CONCLUSIONS: The repetition of the trial produces an optimization of the balance strategy which consists in a reduction of the energy cost (diminution of the muscle activity) and an optimization of the CFP control against an unchanging CoM oscillation. This learning effect is more evident when the visual inputs are denied and when the equilibrium is more challenged.

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Postural orientation in microgravity

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INTRODUCTION: Amblard (1985) has suggested the existence of a dual postural control system, part of which deals with body orientation with respect to gravity and the other, with body stabilisation. Microgravity condition is an exceptional opportunity to isolate the orienting component of posture from the stabilising one. Microgravity suppresses graviceptive information, allowing isolating the proprioceptive contribution to postural orientation with eyes closed. Whether the body orientation depends on the straightening up movement is the main question raised here. Another objective was to specify the compensatory role of visual input while adopting an erected posture during microgravity.

METHODS: The final body orientation was analysed in microgravity during parabolic flights after either 1) straightening up movement from a crouching or 2) a sitting posture, with and without vision.

RESULTS: The main results are the following with eyes open a vertical erected final posture is correctly achieved after sit to stand movement, whereas all subjects were tilted forward after straightening up from a crouching posture.

CONCLUSIONS: These results suggest the existence of a re-weighting of the remaining sensory information, visual information, cutaneous cues and proprioceptive information under microgravity condition. We put forward the alternative hypothesis that the control of body orientation under microgravity condition may also be achieved on the basis of a postural body scheme.

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The effect of age on practice-related changes in postural regulation during continuous, variable amplitude oscillations of the support surface

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INTRODUCTION: It is well documented that postural instability increases with advancing age [1] but generally, there is less consensus regarding age-related deficits in motor learning [2]. Despite impairments in controllability, balance loss could be reduced if practice resulted in longer-term changes in compensatory posture control via postural motor learning. The purpose of this study was to examine the effects of practice on postural regulation in older adults exposed to a perturbation environment with limited predictability.

METHODS: Kinematic data was collected from ten healthy, older adults (66 ± 7.8 years) and compared to previously published data from 12 young adults (24.3 ± 2.8 years) exposed to the same balance task [3]. The task required subjects to stand on a translating platform that underwent random amplitude (range ± 2 to 15 cm) and constant frequency (0.5 Hz) oscillations. Trials were 45-seconds in duration. The middle segment of each trial contained the same sequence of oscillations but subjects were not informed of this feature of platform motion. Subjects completed a practice session on day one (42 trials) and a retention test following a 24-hour delay. Repeated segment data were used to derive spatial (gain) and temporal (phase) measures of whole body COM, trunk, thigh, and shank segment orientation, and lower limb joint angles.

RESULTS: Practice-related changes in older adults were dominated by improved temporal control of the COM, and decreases in trunk tilt variability at a rate comparable to young adults. These improvements did not return to pre-practice levels following a delay period demonstrating longer-term retention. Older adults did persist however with greater COM gain particularly during forward translations, greater knee flexion, and less variability in ankle joint motion, suggesting a more rigid, ‘platform-fixed’ control strategy than young adults, who shifted toward multi-segmental, ‘gravity-fixed’ control.

CONCLUSIONS: Results show that older adults maintain the capacity to learn adaptive postural responses. Improvements in temporal control of COM demonstrate that older adults can extract regularities from the perturbation environment. Reductions in variability of trunk motion for both groups despite differences in lower limb control, support previous evidence that the goal of the CNS in maintaining balance is to limit undesirable trunk motion [4]. Persistence of a simplified control strategy in older adults however, suggests limitations in CNS flexibility. Further, the inflexible strategy predisposes older adults to balance loss by creating a small margin of error for unexpected postural disturbances.

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Dynamic and static balance in visually impaired older adults

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INTRODUCTION: Legal blindness is becoming increasingly prevalent in the aging population. Age-related macular degeneration, for instance, is a frequent cause of legal blindness, affecting more than 25% of people over the age of 70 [1]. Legally blind (LB) older adults are at increased risk of falling [2,3], yet the effect of visual impairment on functional balance is not clearly understood. We hypothesized that people with major visual impairment may compensate to use other sensory systems for balance.

METHODS: Older adults who are legally blind (LB, n=40), with no functional vision (NFV, n=10), or with intact vision (age-matched controls, n=10) were evaluated during quiet stance with a battery of timed balance performance tests (feet together, step stance, standing on foam, unipodal stance, and tandem stance), under eyes open (EO) and eyes closed (EC) conditions. In addition, they were assessed with dynamic balance and mobility tests (overground gait speed, Functional Gait Assessment, Berg Balance scale, and timed repeated sit-to-stand). A subgroup of the LB subjects (n=10) and all the aged matched controls (n=10) also underwent the Sensory Organization Test (SOT) and Adaptation test (ADT) using the SmartEquitest system. One-way ANOVA with Tukey`s adjusted post hoc comparisons were conducted to analyze the difference between the three groups with regard to each balance outcome measure. An independent t-test was used to compare the SOT scores between LB and controls. Finally, a repeated measures mixed model was applied to examine group and trial differences for the ADT scores.

RESULTS: The only quiet stance measures that showed a significant difference between the visually impaired groups and control group (NFV and LB vs controls, p<0.01) were tandem EO scores [(11.8s

(±11.7) vs 16.93s (±12.6) vs 28.0s (±4.7)] and unipodal EO scores [3.8s (±10.9) vs 4.8s (±5.8) vs 12.1s (±6.3)]. In EC testing, none of the tests showed a significant difference between groups. For the dynamic balance tests all showed a significant difference ($p<0.05$) between groups. The SOT results showed a significant increase in sway ($p<0.05$) only in condition 1 (quiet stance), condition 3 (sway-referenced surround) and condition 4 (sway-referenced support). There were no significant differences between groups for the ADT scores, though the LB group tended to show more variability in their responses.

CONCLUSIONS: Contrary to the original hypothesis, our findings showed that older adults with visual impairments do not compensate for their loss of vision by using other sensory cues. When vision was removed under EC testing conditions, the static and dynamic balance scores, as well as the sensory selection strategies employed by visually impaired subjects are similar to controls. Thus, the experience of prolonged visual impairment does not promote better compensation than the controls who are relatively inexperienced in functioning under eyes-closed conditions.

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Motor learning onboard the ISS: the kinematic and dynamic strategies in whole body motor tasks

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INTRODUCTION: Motor function is altered by novel force environments. Then in order to deepen the adaptation processes of motor control system, weightlessness represents one of the most enlightening experimental conditions. Under such extreme conditions, the Central Nervous System (CNS) must completely re-organize sensory and motor processes through adaptive neural responses.

METHODS: Quantitative data concerning motor performances of whole body protocols during prolonged weightlessness were collected, involving so far 2 astronauts engaged in space missions on the International Space Station (ISS). The acquisition of kinematic data was carried out by the innovative Italian facility, ELITE-S2 (ELaboratore di Immagini TElevisive, Space qualified), onboard ISS since August 2007. The defined protocol for this campaign was called MOVE, Movement in Orbital Vehicle Experiments; it scheduled for each session 48 trials, half of trials brushing the target (pointing) and half exchanging force freely with it (reaching). The data analysis was based on biomechanical modelling, where the hip joint center position was estimated by a sphere fit algorithm. The displacement of the center of mass (CM), the focal component of the movement (end-effector trajectory) and the angular and intersegmental coordination were calculated [1]. The joint reaction forces were computed by inverse dynamics [2].

RESULTS: A new motor strategy in 0 g is developed, with a different management of kinematic variables: longer movement duration and greater curved index trajectory, a different coupling of knee angle in the angular coordination and a different displacement of center of mass. Moreover, comparisons between the two protocols were carried out (Fig 1). From the estimated forces and torques at joints, by isolating the inertial components in normal gravity and comparing them with the ones in 0 g, it can be supposed that the minimization of the torque exchange at the interface point assumes a key role in the movement planning.

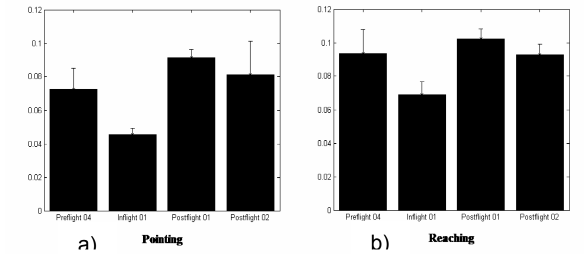

Fig. 1 Center of mass displacement along antero-posterior direction (shift between onset and end on target, [m]), in the following sessions performed by the first astronaut: pre-flight (Launch-23), inflight (FD15), post-flight 1 (Return+2), post-flight 2 (Return+7). Panels a): Pointing; b): Reaching

CONCLUSIONS: From these preliminary results, it can be supposed new sensorimotor strategies in 0 g are developed by CNS in order to perform still efficiently the movement. Other astronauts, other experimental sessions are necessary to enrich information about the motor control learning and its mechanisms.

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The effect of repeated exposure to visual motion stimuli on visual dependence in normal healthy subjects

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INTRODUCTION: Patients with vestibular dysfunction may experience visual vertigo (VV), in which symptoms are provoked or exacerbated by excessive or disorientating visual stimuli (e.g, supermarkets). Patients with VV are believed to be overly reliant on visual input for balance (i.e. visually dependent). VV can significantly improve when customised vestibular rehabilitation exercises are combined with exposure to optokinetic stimuli. However, the exact mechanisms, by which visual dependence can be modified, are unknown. This study aimed to further investigate this issue, by measuring visual dependency before and after repeated exposure to visual motion stimuli in normal subjects.

METHODS: Twenty-six normal healthy subjects (10 Males; mean age 29.8 years, range 21-42 years) without a history of vestibular or neurological disease were randomly allocated into either an intervention group which underwent graded exposure to visual motion stimuli for five consecutive days or a control group which did not receive any intervention. Objective assessment included completing the Rod and Frame and Rod and Disc tests which require subjects to set the subjective visual vertical in darkness, in front of a tilted luminous frame and in front of a rotating disc. Postural sway measures were obtained with eyes open and closed and in the presence of the rotating disc.

RESULTS: Results showed a significant decrease (i.e. improvement) in subjective vertical tilt with the rotating disc only for the intervention group (p = 0.002); no significant changes were noted with the static frame tilt. Postural sway measures showed a significant decrease in the mean deviation induced by the rotating stimulus only for the intervention group ($p < 0.05$). The Kinetic Quotient, which is the ratio between sway path during disc rotation and eyes open and which assesses the destabilizing effect of the rotating disc showed a significant decrease in sway for the intervention group (p = 0.07).The Romberg Quotient, the ratio between sway path with eyes closed and eyes open, showed no change for either group.

CONCLUSIONS: These findings suggest that visual dependency can be improved with short-term graded exposure to visual motion stimuli. The results of this study have important implications for the treatment of visual dependency in individuals with and without vestibular dysfunction.

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Postural balance of obese children under altered sensory conditions

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INTRODUCTION: There is reasonable evidence that obesity imposes significant constraints on postural balance control [1-3]. The decreased stability shown by obese children is generally attributed to their increased noncontributory mass leading to biomechanical inefficiency. Only a few studies suggest that obese children might suffer from perceptual-motor difficulties, i.e. the occurrence of poorer motor behavior when sensory information is needed to plan and control the action [4-6]. However, evidence for such a perceptual-motor point of view is rather scarce and data regarding sensory contributions to postural balance control in obese children are currently lacking. Therefore, it was our objective to examine the influence of normal and experimentally altered sensory conditions on the standing balance of obese children.

METHODS: Sixteen obese children (4 males; 16 females) aged 7-13 years (mean age: 11.2 y; SD: 1.5 y) and the same number of age- and gender-matched normal-weight children (mean age: 11.2 y; SD: 1.6 y) participated in this study. Postural control was assessed in bipedal stance on a force plate (Kistler 9281 B11, dimensions 0.6 m x 0.4 m) in four sensory conditions, given that two types of visual information (eyes open – eyes closed) and two types of plantar cutaneous sensation (normal – reduced) were varied across conditions. Alteration of the plantar afferent information to the postural control system is usually induced by placing foam beneath the feet to create an unstable foot support. Considering the different weight status of our participants, we preferred an ice-induced reduction of plantar sensation through immersion of the plantar surface of both feet in ice-water for 5 minutes prior to balance testing. The actual reduction of plantar sensation was assessed by means of Semmes-Weinstein monofilament examination [7] conducted at five plantar sites on the right foot. During three trials of 30 seconds in each of the four sensory conditions, the children were asked to stand as still as possible with their bare feet 10 cm apart on predetermined marks and with their arms hanging by the sides. Only force plate data of the middle 20 seconds will be retained and implemented in a 2 × 4 (group × sensory condition) ANOVA, with repeated measures on the second factor. The dependent variables of interest are centre of pressure (COP) velocity and sway area.

RESULTS: As data are still being processed and analysed at this time, our results will be presented in detail at the conference and discussed in order to elucidate the relative contribution of sensory information to standing balance in obese versus normal-weight children. One could expect significant group differences because childhood obesity is associated with poorer balance control. We hypothesize that the obese participants will experience more postural balance control difficulties, expressed by greater COP velocities and sway areas, when the sensory condition becomes more challenging.

CONCLUSIONS: The results of this study will lead to greater insight in the possible perceptual-motor difficulties of obese children during postural balance control, which could have an impact on the performance of all motor skills founded on it.

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The effect of changes in body dimensions on the walking pattern of toddlers between 15 and 36 months

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INTRODUCTION: This study is part of a research program that aims at a better understanding of the influence of individual morphological differences and physical growth on the development of walking in toddlers. Several studies emphasised the role of the biomechanical components of the body in determining the walking pattern [1, 2]. In the first three years of life human infants not only experience profound changes in movement capacity but also undergo dramatic changes in body dimensions. In addition the growth pattern is not linear but consists of growth spurts [3]. The question that arises is: how is the walking pattern of toddlers affected when they have to cope with immediate changes in their body dimensions?

METHODS: 15 healthy toddlers between 15 and 36 months of age participated in the study. 3D gait analysis was performed by using VICON motion systems (6 camera's, Mcam 460, 250 Hz). The GRF were recorded with two force platforms (AMTI, 0.5 x 0.4m, 250Hz). The children were asked to walk normal in two conditions, an unloaded condition and a loaded condition with approximately 0.5 kg equally distributed to their legs. Data were analyzed using the Visual3D software.

RESULTS: Preliminary results of 1 child indicate differences in kinematic (Fig. 1) and kinetic (Fig. 2) time profiles between the loaded and the unloaded condition as shown in the graphs.

DISCUSSION: According to the preliminary results leg loading affects the gait pattern of young children. In order to draw conclusions more data need to be analyzed.

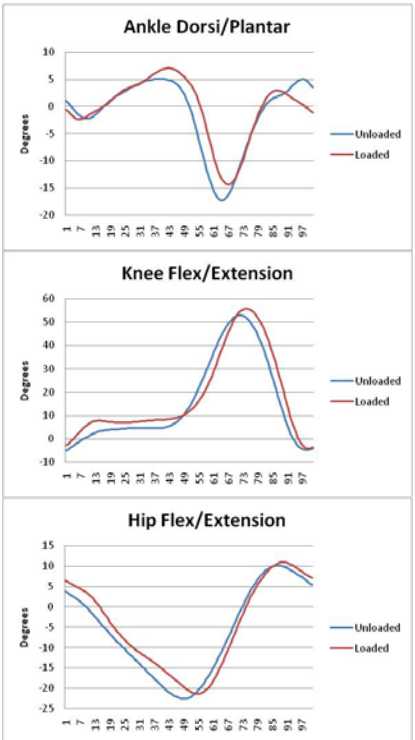

Fig. 1 Angular kinematics

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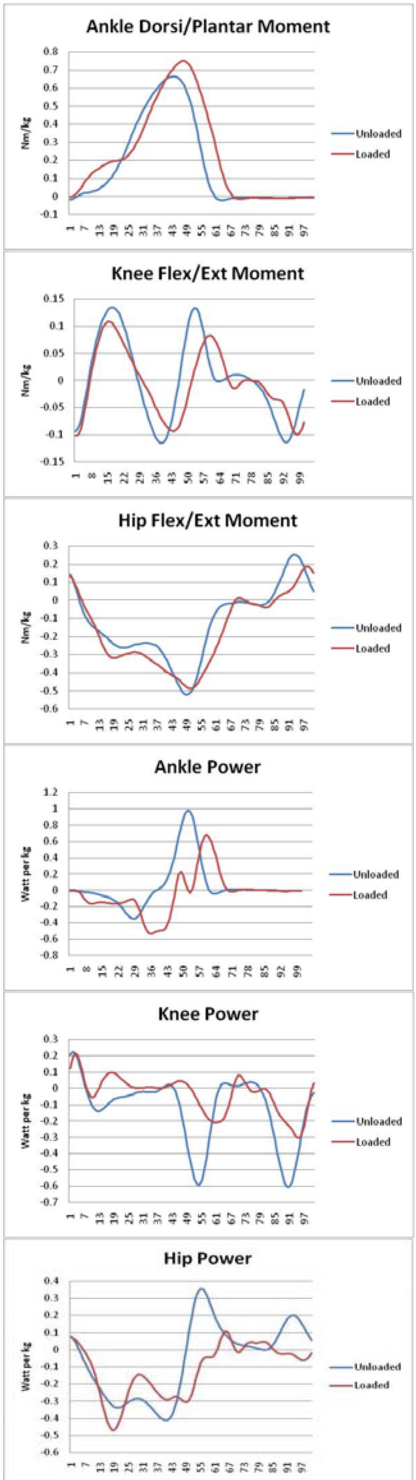

Fig. 2 Kinetic quantities

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Normative data of posturographic indices in Italian children

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INTRODUCTION: Development of postural control in children can be assessed by acquiring force pate data, during quiet standing, in different conditions. Few normative data are available for children in literature. Furthermore, Italian normative data are not available. In this work, we present normative data of a set of commonly used posturographic indices [1-3], obtained from a sample of 80 Italian children.

METHODS: Eighty healthy children (40 M, 40 F), age 4-13 years, participated in the study. Eight children per age (4 M 4 F) were recruited. Children were schoolboys/girls with a normal scholastic level, had a normal neonatal history and had no disease (neurological, orthopaedic, visual) of in their medical history. All children underwent neurological assessment before being included. Age, sex, height and weight were collected. Posturographic data were acquired in four conditions: Normal surface with eyes Open (NO) and Closed (NC), soft surface obtained by customized Pillows with eyes Open (PO) and Closed (PC). In a quiet room, data were acquired by a two-plates portable system (Tetrax, Sunlight, Israel) for 60 seconds, sampled at 50 Hz and low-pass filtered at 10 Hz. The following variables were computed: Sway Path (SP), Stability Index [1], Mean Velocity and RMS amplitude in both the antero-posterior and the medio-lateral direction (MV_{AP}, MV_{ML}, RMS_{AP}, RMS_{ML}), relative spectral power in frequency sub-bands (0-0.1 Hz, 0.1-0.5 Hz, 0.5-0.75 Hz, f>0.75 Hz) and synchronization indices obtained by cross-correlation between fore- and rear-foot forces [1].

RESULTS: Mean values and standard deviations are reported in Figure 1 for SP, SI, MV_{AP} and MV_{ML}, split by age sub-groups. In general, mean values are coherent with data available in literature [2].

CONCLUSIONS: Collected data can be used as Italian normative data in the clinical evaluation of children. Children normative data for quiet standing on a soft surface are new in literature. Based on these posturographic data, the effect of both sex and age on postural development will be investigated and presented.

ACKNOWLEDGEMENTS: This work was supported by a grant of the Italian Ministry of Health.

SwayPath

AGE		NO	NC	PO	PC
4-5	F	241 ± 76	267 ± 80	247 ± 52	347 ± 53
	M	318 ± 143	360 ± 113	358 ± 148	443 ± 110
6	F	191 ± 29	243 ± 56	241 ± 58	398 ± 116
	M	196 ± 24	241 ± 28	234 ± 45	436 ± 101
7-8	F	168 ± 103	179 ± 62	194 ± 39	334 ± 47
	M	216 ± 187	230 ± 133	252 ± 120	356 ± 133
9-10	F	114 ± 12	129 ± 20	148 ± 21	261 ± 57
	M	112 ± 24	151 ± 28	185 ± 32	297 ± 42
11-13	F	102 ± 33	122 ± 27	147 ± 25	264 ± 61
	M	95 ± 21	123 ± 23	145 ± 33	284 ± 87

Stability Index (Sway Path / Height / Weight x 100)

AGE		NO	NC	PO	PC
4-5	F	20 ± 9	22 ± 8	20 ± 6	27 ± 6
	M	26 ± 12	29 ± 9	28 ± 13	35 ± 9
6	F	12 ± 1	15 ± 3	15 ± 3	24 ± 6
	M	11 ± 2	14 ± 2	13 ± 4	24 ± 6
7-8	F	7 ± 4	8 ± 3	8 ± 3	14 ± 3
	M	9 ± 6	10 ± 5	11 ± 4	16 ± 8
9-10	F	4 ± 1	5 ± 1	5 ± 1	9 ± 2
	M	4 ± 2	5 ± 2	7 ± 2	10 ± 3
11-13	F	3 ± 2	4 ± 2	4 ± 2	8 ± 3
	M	3 ± 1	4 ± 1	4 ± 2	9 ± 4

MV_{AP}

AGE		NO	NC	PO	PC
4-5	F	3.2 ± 0.9	3.6 ± 1.1	3.1 ± 0.7	4.5 ± 0.6
	M	4.3 ± 2.0	5.1 ± 1.9	4.3 ± 1.8	5.6 ± 1.3
6	F	2.6 ± 0.5	3.5 ± 0.8	3.1 ± 0.8	5.5 ± 1.8
	M	2.6 ± 0.3	3.4 ± 0.4	2.8 ± 0.4	5.7 ± 1.6
7-8	F	2.3 ± 1.6	2.5 ± 1.0	2.7 ± 0.6	4.4 ± 0.6
	M	3.0 ± 2.7	3.2 ± 2.0	2.9 ± 1.1	4.5 ± 1.6
9-10	F	1.5 ± 0.6	1.7 ± 0.3	1.7 ± 0.2	3.2 ± 0.9
	M	1.5 ± 0.3	2.1 ± 0.4	2.8 ± 0.4	3.9 ± 0.6
11-13	F	1.4 ± 0.5	1.8 ± 0.5	2.0 ± 0.4	3.8 ± 0.9
	M	1.2 ± 0.3	1.7 ± 0.4	1.8 ± 0.4	4.0 ± 1.3

MV_{ML}

AGE		NO	NC	PO	PC
4-5	F	1.8 ± 0.8	1.9 ± 0.6	2.1 ± 0.5	2.7 ± 0.6
	M	2.3 ± 1.0	2.2 ± 0.3	3.3 ± 1.7	3.7 ± 1.2
6	F	1.3 ± 0.2	1.4 ± 0.3	2.0 ± 0.5	2.7 ± 0.6
	M	1.5 ± 0.3	1.5 ± 0.3	2.2 ± 0.5	3.5 ± 0.7
7-8	F	1.1 ± 0.3	1.2 ± 0.3	1.7 ± 0.4	2.5 ± 0.5
	M	1.4 ± 0.9	1.5 ± 0.6	2.4 ± 1.5	2.9 ± 1.3
9-10	F	0.9 ± 0.2	1.0 ± 0.2	1.4 ± 0.3	2.3 ± 0.4
	M	0.9 ± 0.2	1.0 ± 0.2	1.4 ± 0.3	2.3 ± 0.4
11-13	F	0.7 ± 0.2	0.7 ± 0.1	1.0 ± 0.2	1.6 ± 0.4
	M	0.7 ± 0.2	0.8 ± 0.2	1.2 ± 0.4	1.9 ± 0.6

Fig.1 Mean and standard deviation of a set of posturographic indices obtained from a sample of 80 Italian children.

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P.72

Influence of vision on multiplanar sit-to-stand kinematics in children and adults

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INTRODUCTION: Although sit-to-stand motion is a programmed response, sit-to-stand kinematics are modified by immediate task constraints such as seat height, foot position or the presence/absence of arm rests [1, 2]. In this study, we investigate whether immersion in a moving visual environment will similarly produce modifications in sit-to-stand kinematics. We are specifically focused on kinematic changes in the head and trunk in response to the visual field since both the head and trunk have been shown to be highly influenced by visual feedback [3].

METHODS: Nine healthy adults (25-46 yrs) and eight children (8-12 yrs) were seated with knees and hips at 90 deg of flexion and arms at their sides within a 3-wall stereo virtual environment. The command to stand was given in the dark, with concurrent onset of visual scene motion, and following 10 seconds of immersion in a visual scene that was rotated in either pitch or roll with a rotation velocity matched to each subjects' initial standing velocity in the dark. Motion of the head, shoulders, neck, lower back, and hips was tracked in 3-D with a Motion Analysis Hawk system. Sit-to-stand motions were separated into three phases based on the acceleration of the trunk center of mass: (1) sitting to lift-off, (2) lift-off to upright, and (3) upright to standing. A root-mean-squared (RMS) measure of angular velocity was computed for the angular motion of the head with respect to the trunk (head-re-trunk) and angular motion of the trunk with respect to the laboratory in the pitch, roll, and yaw directions for each sit-to-stand phase. RMS velocities during the concurrent, immersion and the dark conditions were compared using repeated measures ANOVA. If the ANOVA was significant, paired *t*-test were used to assess differences between the phases.

RESULTS: For both groups, RMS angular velocities in concurrent trials did not differ from dark. In adults, head-re-trunk and trunk RMS angular velocities in the pitch, roll and yaw planes were significantly ($p<0.05$) reduced following immersion in a visual scene moving in roll compared to concurrent visual motion for all sit-to-stand phases. When the visual scene was moving in the pitch direction, head-re-trunk and trunk angular velocities were reduced in the pitch and yaw planes for all phases and reduced in the roll plane for the first and last phases compared to concurrent motion of the scene or in the dark. Responses in children were not as consistent as in the adults. Trunk and head-re-trunk angular velocities in the pitch, roll and yaw planes were significantly ($p<0.05$) reduced after immersion in the roll scene compared to dark and concurrent visual motion. Immersion in a pitch scene, however, only significantly ($p<0.05$) reduced trunk angular velocity and head-re-trunk angular velocity in the pitch plane across all sit-to-stand phases compared to dark and concurrent visual input.

CONCLUSIONS: Our results suggest that perception of environmental motion modifies the head and trunk kinematics of sit-to-stand behaviors, and that multiplanar motions in children and adults are differentially affected by visual field motion.

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P.74

Children balance: a force platform evaluation

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INTRODUCTION: It might be discussed about the effectiveness/efficiency of balance control capabilities of children that sometimes are thought of as under development and therefore far from standard performances observed in adults. Present investigation was aimed to verify whether children balance control is less effective or generally so different from the one of grown up people.

METHODS: 247 children (146 F+101 M) (7<AGE<10) were given the standard balance test (Romberg Test) on a validated Force Platform. The children were all practising sport disciplines although not at agonistic level. ARGO® Stabilometric Force Platform by RGMD SpA (Genoa Italy) was used. The platform was located at 1 m distance from a white wall devoid of any linear or angular reference (one 1x1 cm black spot was applied at eye level during the Open Eye test). Children were standing with parallel joint feet, mouth losely closed, arms losely hanging aside. Recording was performed for 45 seconds but the first 5 seconds recordings were discarded to take into account adaptation. Closed Eyes Test was performed first to avoid oculomotor memory effects.

RESULTS AND CONCLUSIONS: Besides completing the Normal Population Sample Data, the obtained test results have allowed to propose the following main considerations (see Fig. 1).

1. Children do not show different control characteristics in front of adults. Parameters are in fact within averages – if not "better" – set by "normal" subjects and athletes.
2. From a balance functional point of view children can compare with top ranking athletes. This is evident both from the Open Eyes and the Closed Eyes recordings confirming the excellency of very young Gymnasts.
3. Children – and mostly male children – do show a lack of attention affecting especially the Open Eyes testing. The Test could perhaps be proposed as a screening method for AD-HD in young subjects.
4. The recently proposed SPF index (score of postural functionality) seems to quickly spot the presence of balance disorders/deficits. SPF seems in fact to better notice the balance control alterations that might be connected to attentive deficit.

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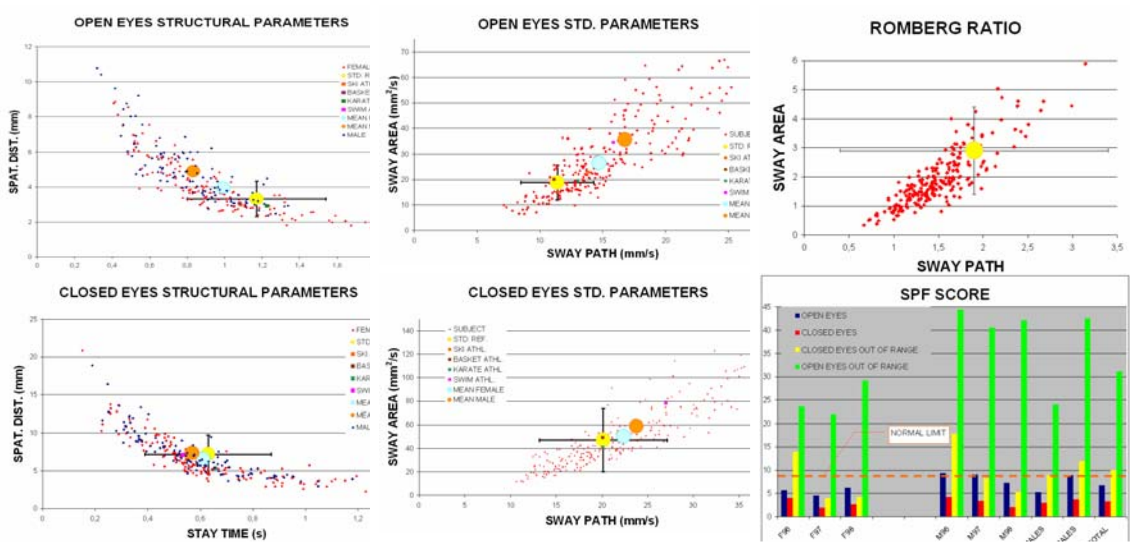

Fig. 1

P.75

The relationship of motor behaviour and task-oriented postural control in children and adolescents with Down syndrome

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INTRODUCTION: The individuals with Down syndrome would have many problems upon motor behaviour and disabilities due to gene variation. In recent years, the researches discussing the motor behaviour and posture stability were mainly focused on the stability of static stance posture rather than dynamic motions. The purpose of this research is to discuss the adjustment on center of pressure for children and adolescents with Down syndrome while they were performing the task oriented postural control of ball throwing.

METHODS: This research gathered 23 Taiwanese participants with Down syndrome and 18 participants without, age-ranged from 10 to 18 years old to assess their gross motor behaviour by Bruininks Oseretsky Test of Motor Proficiency (BOTMP), and further adopted the motion mechanics technique of force plate to appraise the swaying level of the center of pressure. In order to realize the difference of ability for adjusting center of pressure between Down syndrome participants and their normal peers, the task oriented motions of ball throwing were divided into two situations: motion after visual instructions and motion after hearing instructions. After receiving such instructions, the testees should perform the motion of throwing ball to specific spots at the left-front and right-front, and the force plate under their foot would record the counterforce from the floor to them. The data collected included: Displacement in center of pressure (Ax, Ay), the displacement range (ROMPx, ROMPy), trajectory length (TL) and average velocity (V). The displacement of the center of pressure on the two planes was showed by root mean square.

RESULTS: The participants with Down Syndrome had a significant greater displacement(Ax, Ay), than normal peers when accepting visual or hearing instructions ($p = 0.002$, $p = 0.000$), while there was no significant difference in front-and-rear displacement ($p=0.837$, $p=0.897$). The results pointed out that the participants with Down syndrome would be instable in the left and right side. After receiving visual instructions, the normal participants had a significantly larger ROMPy in COP than the participants with Down syndrome ($p = 0.030$), the same pattern occurred in receiving hearing instructions ($p = 0.11$). Such result showed that when the participant with Down syndrome was stiffer when performing task oriented motions. The moving trajectory of center of pressure for participants with Down Syndrome was irrelevant with age, but negatively related to strength and coordination age equivalent ($p=0.017$, $p=0.037$); On the contrary, the trajectory length of normal participants had significantly negative relationship with age. ($p=0.014$)

CONCLUSIONS: Many researches proved that the individuals with Down Syndrome were inferior in static balance, this research further proved the problem remain for them in performing task oriented motions, the balance problem would be a harsh challenge for these individuals. The ability of keeping balance was improved by age in the normal subjects; however the subjects with Down syndrome had to improve their motor behaviour to maintain balance. Most individuals with Down syndrome may improve their strength and coordination, through the guidance with the therapist who realized the relationship between ability of control body center and motor behaviour, to help them being adequate for working. However, more data needed to analyze and discuss the influence of training on strength and coordination.

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P.76

Longitudinal monitoring of gait and mobility in Parkinson's Disease using an instrumented version of the timed up and go test

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INTRODUCTION: The Timed Up and Go Test (TUG) is commonly used in clinical practice and research to assess gait and mobility in Parkinson's Disease (PD) among other patient populations [1]. In the present study, we instrumented the TUG test (iTUG) using portable inertial sensors and monitored PD patients' performance on the test over time. The aim of this study was to find sensitive measures of change in gait and mobility longitudinally in PD using the iTUG.

METHODS: Twelve patients with early-to-moderate PD (UPDRSmotor 20.0 ± 9.4) and 15 age-matched controls participated. All patients were untreated at the beginning of the study; along the 18 months of assessment seven patients started anti-parkinsonian medication. Those on medication were tested in the "off" state. Subjects performed an 8-meter iTUG test at baseline, 6 months (mo), 12 mo and 18 mo. Data was recorded using a Physilog® portable data-logger with 7 inertial sensors attached on the trunk, upper and lower limbs. Gait, sit-to-stand and turning were quantified. A Linear Mixed Models analysis was used to compare groups and follow-ups.

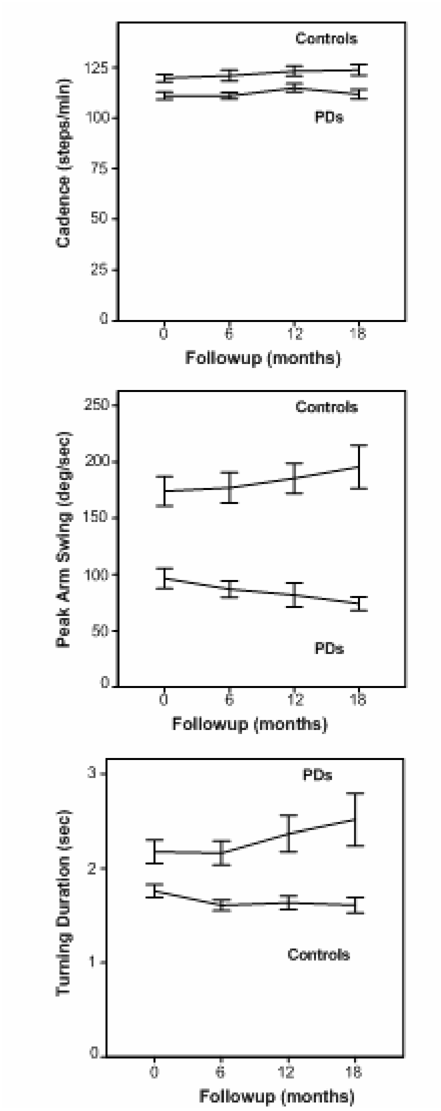

Fig.1 Progression of longitudinal gait and turning parameters in PDs and controls

RESULTS: Among lower body gait parameters, only cadence was significantly different between groups, with PD subjects slower than control subjects ($F=8.7, p=0.05$). There were no effects of follow-up or interaction for any lower body gait parameters, which indicates no decline of gait for either group across 18 mo. Among upper body gait parameters, arm swing amplitude and peak arm swing velocity of the more affected side showed a significant group effect ($F=5.6, p=0.023$; $F=18.9, p<0.001$) and an interaction effect ($F=4.4, p=0.045$; $F=9.6, p=0.004$), indicating a decline of amplitude and speed of arm swing for the PD group, while the control group remained constant throughout the 18 mo. Similarly, turning duration showed a significant group effect ($F=5.0, p= 0.031$) and interaction effect ($F=5.8, p= 0.021$), with turn duration in the PD group increasing over time. The turning peak velocity also showed a significant interaction effect ($F=9.9, p=0.04$). Sit-to-stand parameters were not different between groups or across time.

CONCLUSIONS: The iTUG is a sensitive instrument to detect differences between PD and healthy individuals, and also to detect longitudinal decline of gait and mobility in PD. Variables that were sensitive to the progression of the disease included arm swing and turning parameters, whereas lower body gait variables and sit-to-stand variables were not sensitive to longitudinal changes in early-to-moderate PD.

ACKNOWLEDGEMENTS: This research was supported by grants from the Kinetics Foundation, the National Institutes on Aging and the Oregon Center for Aging and Technology. Dr. Horak was a consultant for the Kinetics Foundation. This potential conflict of interest has been reviewed and managed by OHSU.

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P.77

Effect of age on body segment tilt responses to lower leg muscles vibration

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INTRODUCTION: Balance impairment frequently seen in elderly represents risk factors for falls and subsequent injury, for example fractures. Aging is occasionally accompanied by age-related pathologies, like Parkinson's disease, which hinder independent mobility and lead to postural instability. Adequate postural control depends on the integration of vestibular, somatosensory and visual information about the body motion. The analysis of changes in these sensory systems has shown age-related deterioration and the contribution of the each sensory modalities to balance control is modified by age. Important indicators of human balance control are postural responses to altered sensory inputs. Body lean responses to vibrations of lower leg muscles were investigated in order to understand the influence of age and proprioceptive input from lower leg in human stance.

METHODS: We examined 9 young (24-27 years), 9 older adults (59-70 years) and 5 PD patients (65-76 years) in conditions of bilateral lower leg muscle vibrations (m. triceps surae) with 10s duration at three frequencies 40, 60 and 80 Hz. Subjects performed three trials in each of three conditions of quiet stance on firm surface with eyes closed. Postural responses were characterized by displacement of CoP, by three accelerometers located on the head, the upper trunk (Th4) and lower trunk (L5) level and by kinematics of body segments motion.

RESULTS: Lower leg muscle vibrations induced backward body lean increasing with frequency of vibration and age. The lower body tilts backward were found similar in young, elderly and also in PD patients. The upper body - trunk tilts related to the vertical were minimal in young subjects while in elderly clear backward tilts of the trunk were occurred. An overshoot of the trunk response to vibration offset was found in PD patients. The change of hip angle between the upper and lower part of body was minimal in older subjects, while in young subjects the hip angle changed markedly.

CONCLUSIONS: The findings showed that the trunk response to lower leg muscle vibration is sensitive enough to detect age-related changes in postural control. The trunk and legs tilt to the backward in elderly has major implication for the diagnosis of balance impairment. Furthermore, analysis of the trunk lean by accelerometers may provide useful information about posture deterioration in elderly and in PD patients and should be use also for balance training.

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P.78

Limits of stability of individuals with Parkinson's disease

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INTRODUCTION: Postural instability has been considered one of the main features of individuals with Parkinson's disease (PD). Quantification of the limits of stability may provide an important component of balance, since its reduction can affect the ability to perform daily tasks [1,2]. Therefore, the aim of the present study was to determine if the limits of stability in a normal upright stance varied in individuals with PD.

METHODS: A group of 12 individuals with idiopathic PD, aged 69.7 $\pm$ 7.0 years (range:56-82) and 12 control subjects aged 69.42 $\pm$ 7.74 years (range: 54-84), matched by body mass index and gender were included in the study (four females and eight males in each group). The percentage of body weight supported by each leg, in an upright stance was determined using the weight bearing test. Movement velocity (MV), maximal excursion (ME), and directional control (DC) of the center of mass (CM) in the forward, backward, right, and left directions were quantified for the limits of stability of the *Balance Master System*®. Since most variables related to MV, ME and DC did not have normal distributions, Mann-Whitney-U tests were used to investigate differences between the PD and control group, at a significance level of $\alpha<0.05$.

RESULTS: No significant differences between groups were found for the percentages of body weight supported by the lower limbs. However, as illustrated in Fig.1, PD subjects demonstrated significant decreases in the movement velocity in all directions. ME and DC were also significantly different in the backward, right and left directions (Table 1).

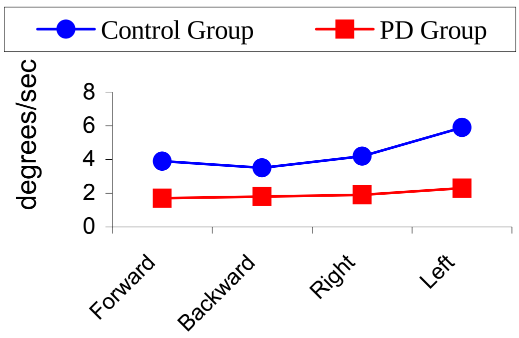

Fig. 1 Movement velocity (degrees/sec) for the PD and control groups

CONCLUSIONS: The findings suggest that in a normal upright stance, the limits of stability of subjects with PD were decreased in the backward, right and left directions.

ACKNOWLEDGEMENTS: Brazilian Government Funding Agencies (CNPq and FAPEMIG).

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Variable		Control Group (n=12)		PD Group (n=12)		
		Range	**Medians**	**Range**	**Medians**	***p***
ME	Backward	85 – 109	98	29 - 95	73	0.000
	Right	78 – 103	96	34 - 99	72	0.003
	Left	83 – 108	99	47 - 91	80	0.000
DC	Backward	79 – 96	87	29 - 91	79	0.014
	Right	84 – 96	90	71 - 91	84	0.012
	Left	85 – 95	91	69 - 93	86	0.028

Table 1 Range [min-max] and medians for the ME and DC of both Groups

P.79

Longitudinal changes in quiet stance in early Parkinson's Disease.

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INTRODUCTION: Previous studies have shown that subjects with advanced Parkinson's Disease (PD) exhibit abnormalities in postural sway during quiet stance [1]. The purpose of this study was to determine if abnormalities in sway are detectable in newly diagnosed, untreated subjects with PD, and if these abnormalities reflect progression of the disease.

METHODS: Longitudinal data were collected in 10 subjects with PD and 13 control subjects at baseline, 6 months, 12 months, and 18 months. The level of PD ranged from mild to moderate (Motor UPDRS = 20.0 ± 9.4). Initially, none of the PD subjects were on anti-Parkinson medication. Over the course of the study, seven of the subjects started medication, but were tested in the practical OFF state. During each session, subjects completed three, 2-minute trials of quiet standing on an AMTI force plate with eyes open. The total body center of pressure (CoP) recordings were obtained from the force plate data and used to calculate anterior-posterior (AP) and medial-lateral (ML) RMS sway and RMS sway velocity measures.

RESULTS: The control subjects had consistent sway parameters across the four sessions with little variability among subjects (Fig. 1, dotted lines). When the CoP was filtered to separate low (0-3 Hz) and high (3-10 Hz) frequency components, the differences between groups and progression with PD across 18m, were apparent only at the higher frequencies of sway (Fig. 1, right column). Both the AP (not shown) and ML RMS sway and sway velocity measures were larger in the PD than the control group for the 3-10 Hz filtered CoP data.

CONCLUSIONS: Our results show that: 1) reliable measures of sway during quiet stance can be measured across 1.5 years and 2) changes in postural sway of PD subjects, especially the high frequency ML RMS sway velocity can be measured before clinically apparent in early, untreated PD subjects. Thus quiet stance measurements could be used as an objective measure of Parkinson's disease over time or in an intervention study. The larger differences between PD and control groups and the larger progression over time at higher frequencies of sway, suggest that PD constraints, such as rigidity and tremor, as well as increased sensory and/or central controller noise impair quiet stance control.

ACKNOWLEDGEMENTS: This research was supported by grants from the Kinetics Foundation. Dr. Horak was a consultant for the Kinetics Foundation. A potential conflict of interest has been reviewed and managed by OHSU.

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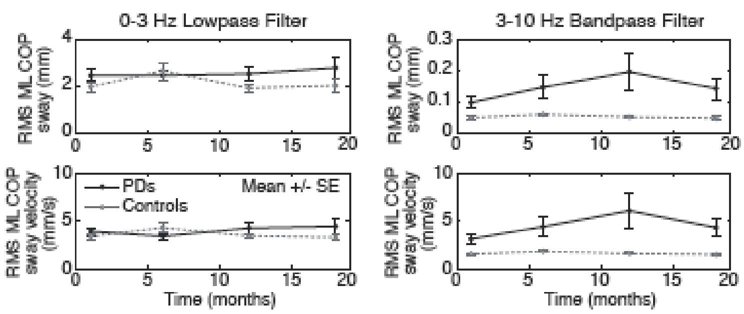

Fig.1 Averaged ML RMS sway velocity of PD and control groups.

P.80

The responses of homonymous muscles of both legs to stance perturbations are differently affected in unilateral Parkinson's disease

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INTRODUCTION: During stance, downward rotation of a platform evokes a polysynaptic response in the stretched tibialis anterior (TA) [1]. The response occurs bilaterally during unilateral perturbation since it is mediated by spindle group II afferent fibres bilaterally feeding spinal and supraspinal circuits [2]. This response is reduced when subjects hold onto a stable frame [3]. We hypothesised that the response excitability and its modulation are impaired in the early stages of Parkinson's disease (PD).

METHODS: Twelve patients with unilateral PD (duration < 2 years, Hoehn-Yahr ≤1.5) and 12 normals (N) were subjected to stance perturbations under the following conditions: 1. both legs on the movable platform during free stance, 2. same as 1, while holding onto a stable frame, and 3. one leg on the platform and the other aside on firm ground. For PD, the single leg perturbation condition was either with the unaffected or the affected limb on the platform. Area of TA response was measured after subtraction of its background value (prior to stretch).

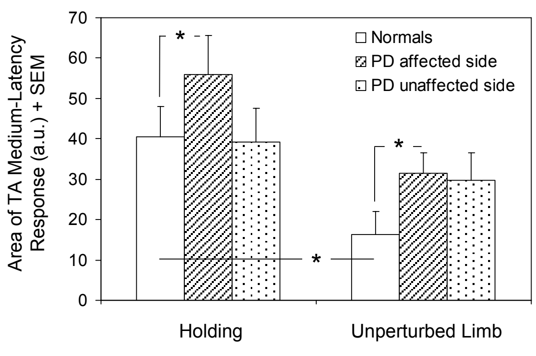

Fig.1 Area of TA response to toe-down rotation of the supporting platform recorded from normal subjects (average of both legs) and PD patients (affected and unaffected leg). During holding onto a frame (left), both limbs were simultaneously perturbed. During unilateral perturbation (right), the responses were recorded only from the unperturbed limb.

RESULTS: 1. Under free stance, the TA response of both limbs was only slightly smaller in PD than in N. 2. During holding, its amplitude was reduced to 40% of free stance in N (Fig. 1). In PD, the response was reduced to a similar extent in the unaffected limb but only to 55% in the affected limb ($P<0.05$). 3. During unilateral perturbation, the response elicited in the non-perturbed leg (either in the affected or in the unaffected) was larger ($P<0.05$) in PD (both sides about 30%) than in N (16%).

CONCLUSIONS: In early PD, excitability of the circuits mediating postural responses is normal, but the response modulation by postural set is reduced on the affected side. Response abnormalities on the unperturbed side show increased excitability of the interneuronal pathway transmitting the input from the stretched muscle to contralateral motoneurones.

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P.81

Abnormal Postural Feedback Scaling in Parkinsonian Disease

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INTRODUCTION: We investigated whether the postural responses of the elderly and age-matched subjects with Parkinson's disease (PD) can be described as a continuous feedback control system, and whether the balance impairment of the subjects with PD can be described as abnormal scaling of postural feedback gain.

METHODS: Seven subjects from each group experienced backward surface translations with 7 different magnitudes ranging from 3~15 cm during 275 msec. Subjects were instructed to stand upright with their arms crossed over their chests, and to recover to their initial upright posture in response to the perturbation without stepping or lifting their heels, if possible. Ground reaction forces and sagittal plane joint kinematics were recorded. A full-state feedback model was used to quantify how the nervous system generates compensatory joint torques to postural perturbations [1].

RESULTS: Ankle joint kinematics and ankle joint torques showed no significant differences in magnitude between the two groups except that the PD patients showed significantly smaller hip sway. Gradual scaling of feedback gains as a function of perturbation magnitude was observed in both subject groups. The elderly showed large decrease of ankle gain accompanied with slight increase in hip gain as a function of increasing perturbation magnitude, but the subjects with PD showed significantly smaller ankle gain, larger hip gain and smaller feedback gain scaling.

CONCLUSIONS: By gradually scaling postural feedback gain, elderly subjects could maintain balance in response to various magnitudes of perturbation without violating maximum allowable ankle torque constraints. Unusually small (bradykinetic) postural responses of subjects with PD can be ascribed to their small ankle and large hip joint feedback gain. Their early violation of the flat-foot constraint is caused by inadequate ankle gain scaling. Using a feedback control gain model, we quantitatively describe the postural abnormality associated with PD as reduced ability to modify postural feedback gain with changes in perturbation magnitude.

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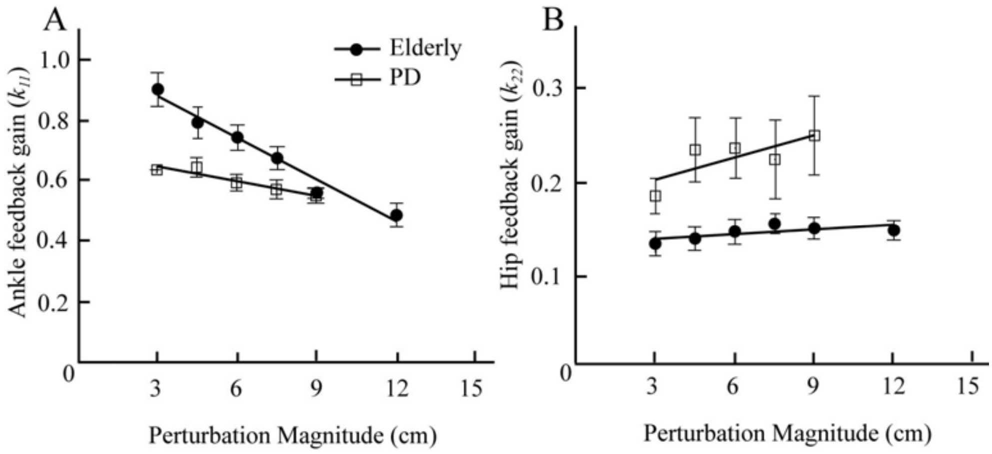

Fig.1 Averaged gain parameters that correspond to (A) ankle angle feedback to ankle torque and (B) hip angle feedback to hip torque of the elderly (filled circles) and subjects with PD (squares). Solid lines show linear regression of the gain parameters as a function of perturbation magnitude.

P.82

Preparation for compensatory forward stepping in Parkinson's disease

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INTRODUCTION: Freezing in Parkinson's Disease (PD) is associated with small anticipatory postural adjustments (APAs) and long latencies of step initiation, especially when APAs must be scaled up for larger stance width [1]. We recently described freezing associated with APAs in response to compensatory stepping to recover equilibrium in PD subjects who had freezing of gait [2]. Here, we characterize anticipatory compensatory stepping strategies for late-stage PD subjects who do not have freezing of gait, using two different stance widths.

METHODS: Postural responses of 18 subjects with moderate to severe PD, in their on and off levodopa state prior to DBS surgery, were compared with 17 age-matched control subjects. Three trials of 24 cm posterior platform translations at 56 cm/s, in both narrow and wide stance, were performed. All subjects required a compensatory step to recover equilibrium. The vertical forces under the initial stepping leg and the contralateral stance leg were assessed for the presence of anticipatory postural adjustments (APA), and categorized into 3 categories: No APA, 1 APA, or multiple APA's. The onset latency and length of the corrective step were measured using kinematic markers on the feet.

RESULTS: Whereas control subjects had no APA in 90% of their trials, regardless of stance width, people with PD, both on and off medication, had a more varied response. Specifically, PD subjects off medication had no APA on 44% of trials, 1 APA on 33% of trials, and multiple APA's on 23% of trials. There was no significant difference in strategy selection between narrow and wide stance for either group and no significant difference between PD subjects on versus off medication. There was also no significant difference in step latency among the 3 groups ($p>0.05$) but the PD subjects had shorter step length, both off (284.4 mm ±20 SEM) and on medication (294.5 mm ±22) when compared to control subjects (383.1 mm±26; $p< 0.01$). Initial stance width did not affect step length ($p>0.05$).

CONCLUSIONS: Unlike voluntary step initiation, subjects with PD used more, rather than less, anticipatory postural adjustments than control subjects, prior to a compensatory step. Also unlike voluntary step initiation, PD did not prolong postural preparation and delay the latency of step onset. Narrowing the base of foot support also did not improve postural preparation, like it does for voluntary step initiation [2]. However, the large percentage of trials with multiple APAs for compensatory steps is consistent with a common postural preparation strategy for voluntary and compensatory stepping. Levodopa replacement therapy did not alter postural strategy selection or stepping characteristics, consistent with lack of improvement of fall risk with anti-parkinsonian medication.

ACKNOWLEDGEMENTS: Research was supported NIA Grants AG06457, AG019706.

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The effects of transcranial electrostimulation on quiet stance and some clinical symptoms in Parkinson's disease

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INTRODUCTION: The effects of subthalamic nucleus (STN) and transcranial magnetic stimulations in Parkinson's Disease (PD) have been well described. At the same time the effects of the transcranial electrostimulation (TES) in PD was unknown. TES selective activates brain antinociceptive mechanisms and has been widely adopted as a method of treatment for different pathology [1].This method doesn't cause subjective troublesome sensation. The aim of our work is the study of the TES effects on the some clinical symptoms and quiet stance in PD.

METHODS: Twenty three idiopathic PD patients (mean age 56,73±16,8, mean stage 1,96±0,67 by Hoehn & Yahr scale, mean disease duration 6,5±3,7 yrs) with prevalence of resting tremor over rigidity were randomized into 2 treatment groups. The first (basic) group consists of 15 patients and 8 other patients were included in the second (placebo) group. TES (frequency of 77 Hz) was carried out via frontal and retromastoid electrodes for during 40 minutes every day. The treatment consisted of 10 sessions. All patients were assessed with the UPDRS (Parts III), PIGD, Fahn scale (for assess of tremor) and were tested with the stabilometry. The analysis of postural sway on a force platform was done using two tests:1) quiet stance with open and closed eyes; 2) stance during mild cognitive task with open and closed eyes. The area of the ellipse and the speed of gravity center measured.

RESULTS: After the course of TES in the basic group the reduction of expression tremor (on 37,74%, $p<0,05$) and the improvement of postural stability (on 28,3 %, $p<0,05$) were observed. Besides the decrease the area of the ellipse (on 60,49 %, $p<0,05$) and the speed of gravity centrum (on 35,64%, $p<0,05$) were noted during the test with mild cognitive task (open eyes). In the placebo group, these rates have not changed significantly.

CONCLUSIONS: These results indicate that the course of TES has a positive effect on the manifestation of such PD symptoms as the tremor and the postural instability. It was hypothesized that postural instability in PD may be caused by impaired noradrenergic mechanisms. It is possible to assume that the basis of the positive effect of TES is the ability to activate antinociceptive system of brain including endorphinergic, GABA-ergic, serotonergic and noradrenergic mechanisms. However this assumption demands acknowledgement in the further researches.**REFERENCES**

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Detecting asymmetries in balance control in Parkinson's disease patients with system identification techniques

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INTRODUCTION: Parkinson's disease (PD) is a progressive, incapacitating neurological disease that negatively affects the quality of life for many reasons, not the least because of severe motor impairments. Symptoms include appendicular disability (including arm rigidity, bradykinesia and tremor) and axial disability (gait disorders, balance impairment, falls and fall-related injuries. PD is typically an asymmetrical disease; symptoms usually start on one side of the body, and throughout the course of the disease, this side remains most prominently affected. Asymmetry of symptoms is clinically clearly evident for appendicular symptoms. However, it is uncertain whether axial disability is also asymmetric. Clinical scales used to assess disease severity (e.g., the Unified Parkinson's Disease Rating Scale (UPDRS) do not explicitly evaluate asymmetries in axial symptoms. Evaluation of asymmetrical balance control will improve our understanding and treatment of axial symptoms.

Methods: In this study, a new method [1, 2] was used to test the hypothesis that balance control in PD is asymmetrically affected. Eight patients with idiopathic Parkinson's disease were asked to maintain their balance without moving their feet during continuous random platform movements, with eyes open (EO) or eyes closed (EC). Body sway angle, reactive forces of each foot and EMG of the lower leg muscles were recorded. These measurements yielded the Frequency Response Function (FRF) of the stabilizing mechanisms, which expresses the amount and timing of the generated corrective torque/muscle activity in response to sway at the specified frequencies. The FRFs were used to calculate the relative contribution of each ankle to the total amount of generated corrective torque and muscle activity to resist the perturbations. In addition, the amount of weight bearing of each leg was calculated. Furthermore, the motor part of the UPDRS and the Hoehn & Yahr disease stage were also evaluated.

Results: Results showed that six out of eight patients exhibited abnormal asymmetrical dynamic weight bearing; one leg was bearing more weight than the other leg. In addition, responses to platform perturbations as shown by corrective ankle torques were also asymmetrical for the same six patients, even more so than the dynamic weight bearing. Hence, one leg contributed significantly more to balance control than the other and there was no clear relationship between the contribution to weight bearing and to balance control. In contrast, a group of healthy subjects instructed to distribute their weight asymmetrically showed a one-to-one relation between weight bearing and balance [1]. Furthermore, the timing of muscle activity was also asymmetrical in patients who exhibited an asymmetrical dynamic balance contribution. No effect of condition (EO/EC) was found.

Conclusions: Balance control in PD patients proved highly asymmetrical. This asymmetry of axial symptoms can be reliably identified with system identification techniques in the frequency domain. In this way, the effects of different treatments such as drug therapy, physiotherapy or deep brain stimulation can be identified for each leg separately. This will provide a better understanding of the pathophysiology of axial symptoms of Parkinson's disease and the effects of different treatments.

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The effect of idiopathic Parkinson's disease on seated trunk reactions

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Introduction: A common symptom of Idiopathic Parkinson's disease (IPD) is decreased trunk and balance control. However the extent to which decreased trunk control may contribute directly to postural instability in patients with IPD is currently unknown. Previous work by Martin (1965) observed that patients with post-encephalitic Parkinson's disease fell in the direction of a lateral tilt when perturbed while seated. Therefore, the goal of this study was to explore kinematic and muscle responses of the trunk in patients with IPD and healthy controls in response to controlled multi-directional seated tilting perturbations.

Methods: Seven patients with IPD (mean age = 70.4 yrs; Hoehn and Yahr = 2.5) and ten healthy controls (68.4 yrs) participated in this study. IPD patients took their normal anti-Parkinson medication prior to the experiment. Participants' range of motion (ROM) was tested actively and passively while lying supine and on their side. Participants were seated on a modified chair and received unexpected tilting perturbations, 7° at 40°/sec, in four different directions (forward, backward, left, and right). Electromyography (EMG) was recorded bilaterally from rectus abdominis (RA), external oblique (EO), and erector spinae ($ES_{T9,\ L3}$) and normalized to maximum voluntary contractions. 3-D kinematics was recorded using OPTOTRAK. EMG onset latencies, amplitudes and peak trunk displacement were analyzed using a between and within subject analysis of variance.

Results: Patients with IPD had decreased active and passive ROM compared to controls in the frontal plane. The co-ordination of muscle onsets to tilting perturbations did not vary between groups in any perturbation direction. There was a trend (p=0.067) for greater amplitude of EO activity in patients with IPD compared to controls. Furthermore, a significant group by direction interaction was observed for ES_{L3} muscle activity (p=0.039) with greater amplitude of muscle activity observed during contralateral directions for patients with IPD compared to controls. Despite these differences, both groups were able to make appropriate trunk corrective movements opposite the direction of the tilt for each perturbation direction. However, the two most severely affected IPD patients were found to make incorrect trunk movements in the direction of the tilt during lateral perturbations. Incorrect trunk movements in these patients were coupled with improperly modulated and timed muscle responses.

Conclusions: Based on our results, we postulate that standing postural deficits in patients with IPD are not attributed solely to trunk control deficits. However, as disease severity progresses trunk control deficits may have a greater contribution to postural instability in patients with IPD.

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A sensitivity comparison of clinical tests of postural instability in patients with Huntington's disease

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Introduction: The aim of the study was to find the most sensitive clinical test for postural instability (PI) in patients with Huntington's disease (HD) and to correlate PI with the other symptoms of the disease. Balance disorder is one of the common symptoms of HD and can occur since early stages of the disease. PI causes falls and resulting injuries and has a large impact on the patient's independence.

Methods: 20 HD patients (11 women, 9 men) were examined using the Unified Huntington's Disease Rating Scale (UHDRS), Mini Mental State Examination (MMSE) and six clinical tests for PI (*pull test, push and release test, stance with feet close together, one-limb stance, tandem stance, and tandem gait*). The postural tests results were analyzed using the factor score showing the degree of instability in each patient. PI was compared with information obtained from surveys for PI and falls completed by the patients and their caregivers independently.

Results: PI was found in 16 out of the 20 patients. The clinical tests correlated better with the caregivers´ answers (r=0.78) than with those from the patients (r=0.51). The validity of the patients´ answers decreased with the MMSE scores. 6 patients were unable to perform the *push and release test.* As factor analysis showed, the *stance with feet close together* and *tandem gait* correlated best with the PI factor. PI correlated with MMSE and with the UHDRS subscore for *voluntary motor activity* and with the overall *motor subscore.* There was also a correlation (r=0.87 (p<0.001) with the *Luria test* (an item of the UHDRS motor subscore).

Conclusions: *Stance with feet close together* and *tandem gait* were found to be the most sensitive tests for PI detection in our HD patients. The *push and release test* could not be completed in 30% of the patients, because of their poor cooperation resulting apparently from their executive dysfunction. The high PI correlations with MMSE and the Luria test point to a relationship between PI and cognitive functions.

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Age-related striatal dopaminergic denervation and severity of a slip perturbation

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Introduction: Striatal dopamine activity declines with age even in the absence of a Parkinson's Disease diagnosis [1]. Age-related striatal dopaminergic denervation (SDD) has been recently implicated in postural control impairments related to the ability to integrate sensory information important for standing balance [2] and to control cadence during normal / unperturbed walking [3]. The primary goal of this study was to analyze the association between the degree of SDD and the magnitude of an unexpected slip perturbation induced during gait.

Methods: Fifty eight healthy subjects aged 20-86 years old (mean 64.3, standard deviation 14.5) underwent [^{11}C]-β-CFT dopamine transporter positron emission tomography. Volumes of interest (VOIs) were defined manually on the SPGR MRI for the striatum in 3D using in-house developed software (VOILand). VOIs were applied on successive dynamic PET frames to generate time radioactivity curves of the regions. Regional cerebral [^{11}C]-β-CFT binding was determined by graphical analysis of the bolus-plus-infusion transformation (BPIT) plot of bolus-only PET experiments [4]. The continuous distribution of [^{11}C]-β-CFT binding potential was used to classify the degree of SDD in three categories: none-mild (75th-100th percentile), moderate (50th-75th percentile) or severe (0-50th percentile). Gait testing included two experimental conditions, specifically, subjects were asked to walk in a known dry environment (baseline) and onto a floor contaminated with a glycerol solution without the participant's knowledge (unexpected slip). Motion data were collected at 120 Hz. The magnitude of a slip was quantified using the peak sliding velocity (PSV), measured at the heel of the slipping foot shortly after heel contact onto the contaminated flooring surface [5]. Regression analyses were used to examine the relationship between the degree of SDD (independent parameter) and PSV (dependent parameter), while controlling for age and other normal walking parameters such as gait speed.

Results: Subjects with none-mild degree of SDD slipped less severely than participants with moderate and severe SDD (p<0.01). Specifically, the mean (standard deviation) PSV for the none-mild, moderate and severe SDD group was 0.70 (0.41), 1.04 (0.49) and 1.04 (0.70) m/s, respectively. Also, SDD explained 15% of the variability in PSV above and beyond that explained by age and gait speed (p<0.01).

CONCLUSIONS: Age-related SDD may be implicated in the ability to recover from large perturbations such as slips and trips. The vestibular and somatosensory systems are responsible for sensing these perturbations but do not have a primary dopaminergic neural substrate [2]. Therefore, our findings suggest an impact of SDD on motor system responses that are required to successfully recover from a slip or trip. These responses need to be fast and require coordinated movements involving multiple body joints. Thus, SDD may have an impact on the onset, magnitude and/or coordination of the response required to recover from a slip or trip.

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Clinical factors associated with self selected gait speed and step variability in diabetic patients walking in a challenging environment

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INTRODUCTION: The World Health Organization has described type 2 diabetes as an international epidemic [1]. The total number of people with diabetes mellitus (DM) is projected to rise from 171 million in 2000 to 366 million in 2030 [1]. Diabetic patients have been shown to suffer from increased risk of injurious falls [2]. Patients' physical activity level, which plays a central role in the management of metabolic diseases, may be reduced as a consequence of falls. However, causes of falls are still subject of debate. Besides diabetic neuropathy, other clinical factors are thought to affect diabetic patients' gait [2]. The aim of this study is to identify clinical factors associated with gait alterations in patients with diabetes.

METHODS: A sample of 76 diabetic patients underwent clinical examination (strength and joint mobility of lower limbs, fear of falls, sensitivity, BMI). Patients were then equipped with the Physilog® system and asked to walk at their preferred walking speed on a tarred pathway and on cobblestones in the garden of the hospital. Gait analysis was then performed using four miniature gyroscopes (ADXRS 250, Analog device) attached to both shank and thigh with Velcro straps. Temporal parameters (velocity, gait cycle time) were estimated from distinctive features of shank angular velocity signal recorded at 200 Hz by Physilog® (BioAGM, CH) [3]. We calculated respective differences in gait performance (speed) and gait variability (coefficient of variation of gait cycle time: CVGCT) while changing terrains. Associations with clinical factors were investigated using correlation coefficients and linear regression analysis.

RESULTS: Regression analysis showed that 36% of the decrease in gait speed was proportionally explained by the mean of maximal isometric lower limb strength (22.2%) (Figure 1a), fear of falls (7.4%) and patients' perceived vibration threshold (6.4%). Moreover we found that the mean maximal isometric strength explained 11.8% of the increase of the CVGCT (Figure 1b) when patients changed from tarred terrain to cobblestones. **C**onclusion: This study showed that both physiological (strength and proprioception), and cognitive-behavioural factors (fear of falls) should be considered when treating diabetic patients with gait alterations. Physical therapists should develop specific treatment programs that improve strength, proprioception, and patients' self-confidence to help them attain WHO's recommended level of daily activity.

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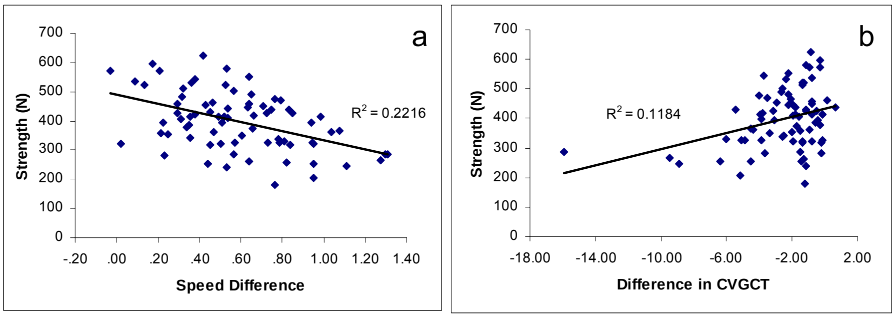

Fig.1 Correlation coefficient between lower limb strength and a) gait speed difference, b) difference in CVGCT

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Balance control in patients with proximal versus distal muscle weakness

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INTRODUCTION: Muscle weakness is an important and consistent risk factor for falls. However, surprisingly little is known about balance correcting strategies in patients suffering from muscle weakness.

METHODS: We examined balance responses to support surface rotations in eight different directions in patients suffering from either proximal (limb girdle muscular dystrophy) or distal (distal spinal muscular atrophy) muscle weakness. Body kinematics and surface electromyography of leg, arm, and trunk muscles were recorded.

RESULTS: Both distal and proximal weakness caused instability of the centre of mass (COM), especially in the pitch plane. COM displacements were generally greater in distal weakness patients. Both patient groups showed increased ankle plantar flexion on backwards perturbations compared to controls. Distal patients also showed increased ankle dorsiflexion when being perturbed forwards. Proximal weakness patients adopted a balance correction strategy involving trunk bending and arm motion, whereas distal weakness patients additionally depended on knee flexion. Distal weakness patients showed increased hamstring muscle activity especially for forward perturbations and increased upper paraspinal and deltoid muscle activity for most perturbation directions. We found few significant differences in muscle responses between proximal weakness patients and controls, but a clear trend was seen for lower responses in quadriceps, hamstrings, and lower paraspinal muscles.

CONCLUSIONS: In conclusion, distal weakness, and to a lesser extent proximal weakness, causes instability after support surface perturbations. Balance correcting strategies included mainly trunk, knee and arm motion; strategies which may be amenable for intervention.

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Balance is impaired in people with chronic respiratory disease

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INTRODUCTION: Recent studies suggest that people with chronic obstructive pulmonary disease have an increased risk of falls [1]. Although falls risk is multifactorial, impaired balance may contribute. To date, only anteroposterior balance has been investigated in this population [2] and there has been no consideration of mediolateral balance, even though it is argued to be more closely related to falls [3]. The primary aim of this study was to compare anteroposterior and mediolateral balance performance in people with and without chronic obstructive pulmonary disease. The secondary aim was to determine if balance deteriorates when respiratory demand is increased following exercise.

METHODS: Twelve people with chronic obstructive pulmonary disease and 12 healthy control subjects matched for age, gender and activity level stood on a force plate to record centre of pressure displacement (mean and root mean square amplitude) during a range of conditions that challenge balance: eyes open, eyes closed, standing on foam, standing on a short base. Lumbar spine and hip motion in the sagittal plane were measured with three inclinometers. Trials were performed before and after participation in upper limb exercise that increased respiratory demand in people with chronic obstructive pulmonary disease.

RESULTS: People with chronic obstructive pulmonary disease had increased mediolateral displacement of the centre of pressure and increased angular motion of the hip compared to healthy controls. Following exercise, mediolateral centre of pressure displacement was further increased in people with chronic obstructive pulmonary disease, but unchanged in control subjects. There was no difference in anteroposterior displacement of the centre of pressure between groups either before or after participation in exercise.

CONCLUSIONS: People with chronic obstructive pulmonary disease have impaired balance in the mediolateral direction which may contribute to the increased risk of falls in this population. Increased mediolateral centre of pressure displacement may be due to reduced ability of the trunk to contribute to the maintenance of balance, possibly as a result of increased respiratory and postural activity of the trunk muscles.

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Postural muscle-modes synergies in mild cerebellar ataxia

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INTRODUCTION: We studied the coordination of postural muscle activity during self-induced perturbation used by the framework of the uncontrolled manifold hypothesis [1, 2]. A major question was: Does the coordination of postural muscle control to stabilize important performance variables in cerebellar ataxia decrease while the feed-forward and feed-back control in comparison to the control group?

METHODS: 9 patients with mild cerebellar ataxia, walked independently, and 9 healthy adults participated in this study. The subjects stood upright on a force platform while holding a load (5% of body weight) suspended behind the body through the pulley system with extended arms. They were instructed to release the load in a self-paced manner with a quick abduction of bilateral shoulder joints. Each subject repeated the task for 50 trials [3]. All trials were aligned according to the first change in the signal from the accelerometer attached on the load (time zero: t_0). EMGs of 10 postural muscles were analyzed (tibialis anterior, medial and lateral head of gastrocnemius, soleus, rectus femoris, vastus lateralis, biceps femoris, semitendinosus, rectus abdominis and lumbar erector spinae). Principal component analysis was used to identify muscle groups (M-modes) within the space of integrated indices of muscle activity obtained from EMG signals. Variance in the M-mode space was partitioned into two components within each 25ms window from 500ms prior to 200ms after to t_0, one that did not affect the average value of COP_{AP} shift ("good variance") and the other that did ("bad variance"). An index (Delta-V) was computed reflecting the relative amount of the "good variance"; this index has been interpreted as reflecting a multi-M-mode synergy stabilizing the COP trajectory [4-5].

RESULTS: M-modes accounted similar across two groups of the total variance, the average ± S.D. of the patient and control group were 67.9 ± 3.3 and 65.9 ± 4.8, respectively ($p > 0.05$). Linear relations between changes in the magnitudes of M-modes (ΔM) and the COP anterior-posterior shifts (ΔCOP_{AP}) were assumed and the corresponding multiple regression equations computed over the trials performed by each subject separately. There were also similar relations between changes in the magnitudes of ΔM and ΔCOP_{AP} (the Jacobians) across groups, the average ± S.D. of the patient and control group were 77.2 ± 10.0% and 82.2 ± 6.1%, respectively ($p > 0.05$). Surprisingly, the average values of Delta-V were similar across groups from -500ms to +50ms. However, the average values of Delta-V in patients decreased significantly in comparison to those of control group after 50ms to t_0 ($p < 0.05$).

CONCLUSIONS: The results indicate that the coordination of feed-forward postural muscle control to ensure stable COP trajectories maintains intact, but that of feed-back control becomes impaired in patients with mild cerebellar ataxia. Central nervous system may do not need cerebellar function contribute to the coordination of natural anticipatory postural adjustments.

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P.92

The effect of lesions to the olivo-cerebellar pathway on obstacle avoidance locomotion in rat

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INTRODUCTION: One essential task of the locomotor system is to avoid obstacles that impede walking. Step over an obstacle during locomotion requires appropriate intra-limb coordination, to adapt for height and width of the obstacle. The cerebellum plays an important role in intra- and inter-limb coordination during locomotion. Climbing fibres (CFs) which originate from the inferior olive (IO), these synaptic actions to the Purkinje cells are necessary for the synaptic plasticity in the cerebellum and motor learning. Previous study reported that CFs responses are apparent in low frequency and are not dependent to the locomotor phases. However, perturbation induced Climbing fibre responses in very high probability [1,2]. When CFs input was diminished, spontaneous simple spike firings of the Purkinje cell were abnormally enhanced [3]. Our question has been – are the IO neurons and their CFs inputs necessary for on-line control of ground locomotion and/or obstacle avoidance during locomotion?

METHODS: Pharmacological lesions of the IO was achieved by administration of 3-acetylpyridine. In pre- and post-lesions, ground locomotion and obstacle (Height 2cm 3cm 4cm) avoidance were recorded by high speed camera system and were analyzed. All procedures relating to the care and treatment of animals conformed to the guidelines established by the Animal Investigation Committee of The University of Tokyo and The United States National Institute of Health.

RESULTS: In IO lesioned rats during ground locomotion, they changed gait pattern and collapsed inter-limb coordination of homolateral, homologous, diagonal coupling. IO lesioned rats had excessive toe elevation during swing phase. Moreover, they exhibited hyper flexion of Hip, Knee and Ankle joint. Therefore, intra-limb coordination was severely impaired. In the step over an obstacle, toe trajectory of hindlimb was distorted and excessive toe elevation was more enhanced than that during ground locomotion.

CONCLUSIONS: These data indicate that olivo-cerebellar pathway plays an important role of inter- and intra-limb coordination during ground locomotion and the production of the adaptive trajectory during obstacle avoidance.

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P.93

Locomotor adaptation and aftereffects in patients with reduced somatosensory due to peripheral neuropathy

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INTRODUCTION: Although studies on neuropathic gait abound, gait adaptation and aftereffects in peripheral neuropathy patients (PNP) have been neglected.

METHODS: We studied 12 PNP and 13 age-matched controls in the moving platform (or ‘broken escalator’) aftereffect to see how somatosensory loss affects locomotor adaptation and, in particular, whether leg proprioceptive input is responsible for the release and the recovery (‘braking’) of the forward trunk overshoot observed during the aftereffect. Trunk displacement, foot contact signals and leg EMG were recorded whilst subjects walked 1) onto a stationary sled (BEFORE trials), 2) onto the moving sled (MOVING, or adaptation, trials), and 3) again onto the stationary sled (AFTER trials).

RESULTS: As expected, PNP were significantly unsteady during the MOVING trials; however some adaptation (i.e. progressive reduction of unsteadiness) was observed. During the AFTER trials, both groups expressed an aftereffect, shown as increased approach gait velocity, a forward trunk overshoot and raised leg EMG levels with respect to BEFORE trials. However, over half of the PNP (58.3%) did not show a trunk overshoot, in contrast to less than a quarter of normal subjects (23.1%), although this did not correspond with clinical severity. Splitting PNP into two subgroups (with/without trunk aftereffect; +/-ae) showed that PNP–ae tended to adapt to the MOVING trials by increasing their distance travelled, which subsequently was expressed as an increase in distance travelled during the aftereffect, rather than as a trunk overshoot. This motor pattern was not seen in normal controls suggesting that, as a result of somatosensory loss, some PNP use a distinctive strategy to negotiate the sled, in turn resulting in a distinct aftereffect. It was also noted that termination of the LAE was not significantly affected by somatosensory loss in patients, despite subgroup; this was explained by the findings that ‘braking’ EMG bursts in medial gastrocnemius were anticipatory (rather than sensory-triggered) and that these EMG bursts occurred earlier in PNP than in NCs.

CONCLUSIONS: We conclude that sensory input is not critical for the emergence or termination of the LAE, although somatosensory loss can induce profound changes in motor adaptation. In particular, our study has identified individual differences in CNS adaptive motor performance, indicative that PNP adopt different feed-forward gait compensatory strategies in response to peripheral sensory loss.

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Comparing psychophysical detection thresholds to very short postural perturbations in mature adults with and without diabetes

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INTRODUCTION: Small postural disturbances that are shorter than typical sway path lengths and with velocities on the order of sway velocities might or might not be strong enough to be detected or to activate physiological systems. Such perturbations are "buried" in the "noise" of normal sway; and as such, require psychophysical techniques to determine whether they can be reliably detected. The resultant perceptual stimulus-response (S-R) curve differs between those with and without diabetes (DM), but surprisingly independent of the presence or absence of peripheral neuropathy (PN) [1]. This paper quantitatively compares such S-R curves of adults with and without DM.

METHODS: 69 adults, ≥50 y/o, (25 with Type II DM, and 44 without DM) were recruited. While blindfolded, subjects stood on a SLIP-FALLS sliding platform. It eliminates move-ment vibration and other extraneous cues by floating on air bearings and by using a non-contact linear motor [2]. Psychophysically, each subject was required to choose in which of two sequential intervals that a short anterior perturbation was presented. With a 2AFC PEST testing procedure [3], the stimulus amplitude (peak acceleration) was it-erated over a 30 trial run until detection threshold was reached. Thresholds were deter-mined over separate runs at fixed 1, 4, and 16 mm anterior displacement perturbations.

RESULTS: For both groups, the relationships between displacement and the peak test acceleration at threshold follow an inverse power-law $PAT=a*(Displ)^{-b}$ [Fig 1], as previ-ously seen for young adults (YA) [4]. On a log-log plot, the slopes are nearly identical and lines parallel, but the multipliers differed by a multiplicative factor of approximately 1.6. The thresholds for the DM and Non-DM groups were statistically different [1].

CONCLUSIONS: Power-law trades are often seen is stimulus-response tests. Shorter dur-ation stimuli require higher intensities to be detected (Block's law). Parallel lines suggest that the same modality is providing perception for both groups. The offsets mean that sensitivities differ. The obvious cause for the latter would be diabetic PN. However, the presence or absence of PN was not a significant factor, nor was weight a significant covariate [1]. Move time is not the cause, since it is shorter at any fixed move for DM's higher acceleration. Velocity at threshold increases with displacement [Fig. 2]. Tracing iso-acceleration lines (Fig.1) shows that the DM group needed ≥2X the displacement of NoDM for detection at a given acceleration. From the iso-velocities of Fig. 2, DM needs ≥4X the displacement length to detect compared to NoDMs, and ≥10X of YA's. These increased detection lengths could well be a contributing factor to falls initiation by DMs.

ACKNOWLEDGEMENTS: Research was supported by a VA Senior Rehab Research Career Sci-entist Award, VA Rehab R&D Merit Review E01-2097R and NIH NIA grant R01 AG026553.

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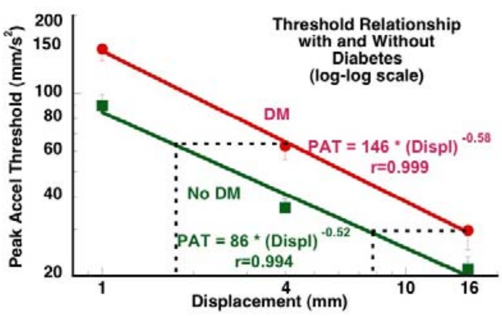

Fig. 1 Stimulus-Response curves of PAT vs Displ. for diabetics (DM) and No DM

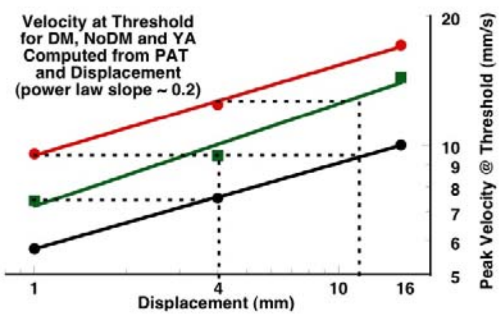

Fig. 2 Relationship between Threshold Velocity and Displ for DM, No DM and YA [4]

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A multi-task gait analysis approach: normative data and pilot application to young CMT subjects.

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INTRODUCTION: Charcot-Marie-Tooth (CMT) disease is an hereditary sensory-motor neuropathy, whose prevalence is 1 out of 2500, the CMT type 1A being the most frequent. Widely observed symptoms are lower limb distal muscle deficit and foot deformity, frequently resulting in gait disorders such as foot-drop and plantar-flexion deficit, decreased gait speed and increased fall-risk [1, 2]. At early stage CMT – like many other neuromuscular disorders – may not drastically affect the basic gait ability, though accessory more demanding locomotor functions (such as toe- and heel-walking and stair negotiation) may be clearly compromised. Moreover, increased gait speed may emphasize functional limits not easily observed at natural speed. To go beyond the limits of standard gait analysis we therefore propose a wider multi-task protocol.

METHODS: The protocol we propose includes analysis of gait at natural and increased speed, and, additionally, toe- and heel-walking, stair ascending and descending. It gained approval from our Ethical Committees. Normative kinematic and dynamic data were collected from ten young voluntary healthy subjects, aged from 8 to 15 years. To demonstrate a profitable application we also present data from a sample of young CMT 1A patients.

RESULTS: Patients' natural speed was slightly decreased in comparison to healthy subjects' (0.75+/-0.12 vs. 0.87+/-0.13 m/s, p<0.001). Matched-speed comparison evidenced slightly increased cadence and reduced step length. Foot-ankle alterations (foot drop at swing, limited ROM, push-off and weight-acceptance deficit) were frequently observed, particularly in the additional more demanding locomotor tasks, as fig. 1 and 2 show considering one normal subject and one CMT as example. Accordingly, compensation strategies were observed at knee or hip level.

CONCLUSIONS: The multi-task protocol we propose can give a more accurate description of a subjects' gait functionality than a standard gait analysis exam. It proved that additional tasks are more likely to show alterations in mild affected patients. It can be used to quantify CMT gait impairment, with possible application in treatment decision making and patient's follow up.

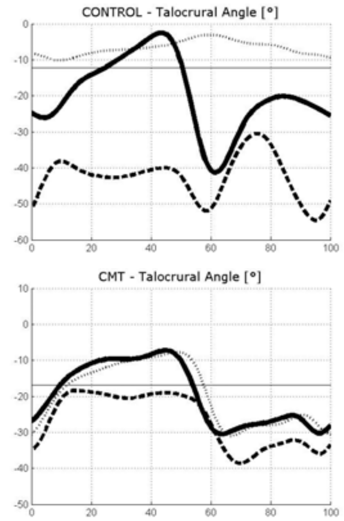

Fig.1 Ankle angle in Gait (continuous thick line)/Heel gait (dotted line)/Toe gait (dashed line). Thin line: standing value.

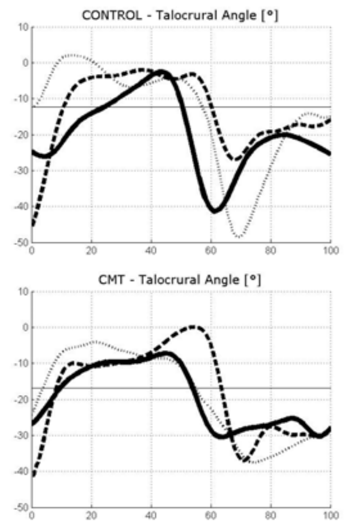

Fig. 2 Ankle angle in Level walking (continuous thick line)/Ascending stairs(dotted line)/Descending stairs(dashed line). Thin line: standing value.

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The influence of posture on the pattern of whole-body instability in freely-standing subjects with spino-cerebellar ataxia type 6

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INTRODUCTION: Spino-cerebellar ataxia type 6 (SCA6) is a genetically identifiable cerebellar ataxia with relatively ‘pure’ pathology i.e. localised to the cerebellum. It is clinically characterised by impaired balance and ataxia of movement, frequently causing falls [1]. The balance control processes affected by the disease are unknown. As an important first step in understanding these processes, we have studied the pattern of whole-body instability in freely standing subjects and measured how the pattern is influenced by posture and whether it correlates with clinical scales of disease severity. In particular, we have studied whether the pattern of instability has a directional preponderance and whether it is localised to specific joints of the body.

METHODS: Seventeen subjects with SCA6 were recruited together with a group of seventeen matched healthy controls (HCs). Whole-body measures of posture and balance were collected using Coda 3D-motion capture (Charnwood Dynamics) over forty-second trial durations, whilst subjects stood quietly on a force plate (Kistler) with their eyes open and with a variable stance-width posture (from feet together to 32cm apart). Clusters of infrared-emitting diodes were fixed securely to each of the body segments (head, trunk, pelvis, thighs and feet). Anatomical landmarks were referred to these clusters for off-line analysis of joint angles using Visual3D software (C-Motion). Clinical assessment of disease severity was measured using the Scale for Assessment and Rating of Ataxia (SARA) [2].

RESULTS: Global measures of instability, from motion at the level of C7 and centre of pressure of ground reaction forces, revealed that SCA6 subjects were more unstable than control subjects in both anteroposterior (AP) and mediolateral (ML) directions at all stance widths. For both groups, standing with the feet closer together caused greater instability in both cardinal directions. However, this stance-width effect was disproportionally large in the SCA6 group in the ML direction (group x stance width interaction; $p<0.001$). Analysis of joint angle motion showed that the excessive instability of the SCA6 subjects when standing with their feet together occurred at all joints but with most angular motion taking place at the ankle joint. A number of measures of whole-body instability were found to correlate with disease severity.

CONCLUSIONS: We conclude that the stance-width posture of SCA6 subjects is an important determinant of their pattern of standing instability and helps to explain why many subjects spontaneously adopt a wide-based posture. Correlations between quantitative stability measures and the SARA indicate that this score could be used not only to monitor overall disease severity but also as a balance impairment predictor. These findings will facilitate further investigation concerning the pathophysiology of balance control in SCA6 as well as contributing towards the assessment of future targeted therapies.

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Balance control in spino-cerebellar ataxia type 6: vestibular processing unravelled

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INTRODUCTION: The spino-cerebellar ataxias (SCAs) are a group of inherited and neurologically degenerative disorders that frequently cause atrophy of the cerebellum [1]. SCA6 is clinically characterised with impaired balance and ataxia of movement, frequently causing falls [2], and is considered to be one of the SCA types with the purest pathology due to the relatively localised signs of neuronal damage in the cerebellum. The disordered control processes responsible for the balance impairment in this group remain undetermined and consequently no management guidelines exist [1]. Animal experimentation has suggested that areas of the cerebellum, such as the anterior cerebellar vermis, flocculus and spino-cerebellum have roles in vestibular gain control, sensory integration and timing [3]. Dysfunction of these areas could cause poorly scaled, directed or timed balance responses, any of which could be responsible for impaired balance control. Since SCA6 is known to involve Purkinje cell atrophy particularly in the anterior and superior cerebellar hemispheres and vermis [1], it is reasonable to hypothesise that poor balance may result from impaired vestibular processing associated with these regions. Here we investigate whether SCA subjects can use vestibular information appropriately to control balance, in particular to integrate vestibular information with other sensory inputs.

METHODS: Seventeen subjects with SCA6 were recruited together with a group of seventeen matched healthy controls. Subjects stood quietly on force plates (Kistler) with their feet 8cm apart and with different head yaw directions (head forward or right/left 90 degrees). Clusters of infrared-emitting diodes were fixed securely to each of the body segments and body motion was recorded in 3D using Coda (Charnwood Dynamics). Galvanic vestibular stimulation (GVS, 1mA bipolar R+L-/R-L+) was used to provide a standardised and repeatable vestibular balance perturbation and visual conditions (vision intact/obscured) were varied using liquid crystal spectacles (Plato).

RESULTS: In both groups, average responses to GVS were normally timed and normally directed (along the intra-aural line, towards the anodal ear). Furthermore, average response magnitudes typically increased with removal of vision, as did baseline instability measures in both groups. However, despite these many similarities to healthy controls, in all conditions SCA6 response magnitudes were consistently larger than those of the healthy control group.

CONCLUSIONS: These results suggest that abnormal vestibular processing is probably not the main determinant of SCA6 instability. However, SCA6 subjects' 'over-response' to GVS could contribute to instability and may be due either to an abnormal increase in gain of the vestibular channel of balance control or an epiphenomenon of the subjects' greater baseline instability.

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Gait characteristics and predictors three months after hip fracture

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INTRODUCTION: Hip fractures in elderly are a major affliction for both the patient and the society. They are most common in frail older persons at high age, and are associated with extremely poor outcome such as high mortality, strongly reduced function, and increased risk for new falls and fractures [1,2]. Relatively little is known about gait characteristics after hip surgery other than through self-reports. The aim of this study was therefore to investigate gait characteristics three months after hip surgery and establish which factors may predict gait outcome.

METHODS: Participants consisted of 88 hip-fracture patients (mean age 81.6 ± 5.8 yrs). Background variables were ADL (Barthel Index and Nottingham Extended), Mini Mental State Examination, Falls Efficacy Scale, Timed Up-and-Go, Pain numeric rating scale, age, gender, BMI, type of fracture, and surgery type. Gait characteristics were measured three months post surgery using an electronic gait mat. Participants walked back and forth the gait mat twice at slow, preferred and fast speeds, without walking aid if possible. Selected gait parameters were walking speed, cadence, step length, step width, and single support. We calculated within-subject means, asymmetry ratios (affected/unaffected), and variability (CV). Gait characteristics of 165 healthy elderly (mean age 79 ± 5 yrs) were used as reference data.

RESULTS: Results indicated that hip-fracture patients had significant reductions in Barthel Index and Nottingham Extended scores, and a strong increase in the use of walking aids three months post-surgery compared to pre-fracture function. Compared to the reference group, hip-fracture patients walked slower with shorter steps, shorter single support phases, increased step length variability, and increased asymmetry in step length and single support phase. Apart from step length variability, these differences remained after controlling for walking speed. Multiple linear regression within the hip-fracture group, with gait characteristics three months post-surgery as dependent variables, demonstrated that speed was the single most significant predictor. Other predictive variables were age (all measures), BMI and pain (mean and CV of step length and single support), ADL and fracture type (variability measures), and walk aid (step length and single support).

CONCLUSIONS: Gait three months after hip surgery is characterized by high asymmetry and variability. In combination with slow walking speed, small steps, and long double support phases, these gait characteristics reflect high risk for new falls, with associated further functional loss. The predictive value of multiple background variables for gait characteristics reflects the complexity of functional loss in elderly hip-fracture patients.

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Altered proprioceptive control induced by inspiratory muscles fatigue in persons with and without recurrent low back pain

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INTRODUCTION: Postural stability can be challenged by external and internal (e.g. respiration) perturbations. Normally the central nervous system can deal with these challenges by counteracting with small movements of multiple joints [1]. Recent evidence suggests that the postural compensation for the respiratory disturbance may be less effective in people with low back pain (LBP) [2]. This can explain the increased postural sway and the use of a rigid proprioceptive postural control strategy in persons with LBP[3]. Insight into the mechanisms of this postural control impairment might assist the management of LBP. The role of the respiratory muscles in postural control remains unclear, but can be studied by inducing acute fatigue of the inspiratory muscles. The aim of this study was to examine the influence of inspiratory muscles fatigue (IMF) on postural stability and proprioceptive postural control strategies in people with and without recurrent LBP.

METHODS: Postural control characteristics of 16 subjects with LBP and 12 healthy subjects were evaluated both before and after IMF. To evaluate postural stability, center of pressure (CoP) displacement was determined on a force plate. Muscle vibration was used to evaluate the role of proprioceptive signals in postural control. Ratios of CoP displacement measured during triceps surae muscles vibration to that measured during lumbar paraspinal muscles vibration determined the proprioceptive postural control strategies. All trials were performed on both a stable as unstable support surface and without vision. Acute IMF was induced by breathing against an inspiratory threshold load.

RESULTS: After IMF, healthy subjects showed a significantly larger sway compared to the unfatigued condition, while standing on the unstable support surface ($p<0.05$). They increased reliance upon proprioceptive signals from the ankles, which is similar to people with LBP ($p<0.05$). Subjects with LBP showed that same ankle steered postural control strategy in both the unfatigued and IMF states ($p>0.05$).

CONCLUSIONS: During postural perturbation, IMF has a disturbing effect on postural stability in healthy subjects. The use of a rigid proprioceptive postural control strategy, rather than ‘multi-segmental’ control, due to IMF, might explain this observed postural instability. This resembles the behavior of people with LBP during an unfatigued condition. These findings suggest that inspiratory muscle training associated with postural control coaching might assist in the management of recurrent LBP.

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Differences in functional recovery of patients with total knee or total hip arthroplasty: one year postoperatively

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INTRODUCTION: Patients with severe end-stage osteoarthritis (OA) are treated with a total knee (TKA) or total hip (THA) prosthesis. For rehabilitation purposes, it is important to know if the prosthetic leg restores its function and if there is a functional difference between TKA and THA patients. The sit-to-stand movement (STS) has proven to be an effective and discriminative instrument for measurement of knee function. During STS, patients can use two strategies to unload the impaired leg. They can reduce the leg extension velocity (=kinematic) and/or rise asymmetrically (=kinetic), thereby overloading the contralateral leg. In this study, we used the STS to quantify if a prosthetic placement restores the functional capacity for both knee and hip patients.

METHODS: 11 TKA (median age=63.0 (25^{th}-75^{th} percentile=54.1-70.6)), 10 THA patients (age=58.4 (49.7-63.2)) were measured pre- and 1 year postoperatively, and 21 control subjects (age=62.0(56.1-72.9)) were measured once. The STS movement was performed 10 times without use of arms, with rest in between, from 90º knee flexion from a chair with adjustable height. The leg extension velocity (kinematic strategy) was quantified as the maximal knee angular extension velocity (VELOCITY_KNEE) and hip angular extension velocity (VELOCITY_HIP) and was measured with sets of bi-axial accelerometers and a gyroscope on lower and upper leg and sternum [1]. The asymmetry (=ASYM, kinetic strategy) was measured with 2 forceplates and defined as:

$$ASYM = \frac{Peakforce\_prosthesis}{Peakforce\_contralateral}$$

RESULTS: Preoperatively, knee and hip patients rose with smaller VELOCITY_KNEE and VELOCITY_HIP than the control group (p=0.001), but there was no difference between the two patient groups (p=0.3, table 1). Placement of TKA and THA prostheses restored the kinematic function of patients, one year postoperatively. Preoperatively, both patient groups showed asymmetry compared to value 1 (=perfect symmetry). Furthermore, hip patients showed more asymmetry (see fig 1). Placement of TKA normalized the kinetics, whereas patients with a THA still showed asymmetry.

	VELOCITY _KNEE		VELOCITY_HIP	
	Pre (°/sec)	Post (°/sec)	Pre (°/sec)	Post (°/sec)
TKA (n=11)	91.3* 74.2-94.9	92.4 79.6-123.4	124.3* 103.4-136	137.9 109.7-183
THA (n=10)	90.8* 83.8-118.3	111.0 93.6-118.5	126.6* 110.2-176	141.9 127.5-175
Control (n=21)	130.5 103.3-150.7		184.1 148.5-206.5	

Table 1: VELOCITY_KNEE and VELOCITY_HIP (median, 25th-75th percentile). * Significant difference between patient and control groups (p<0.05)

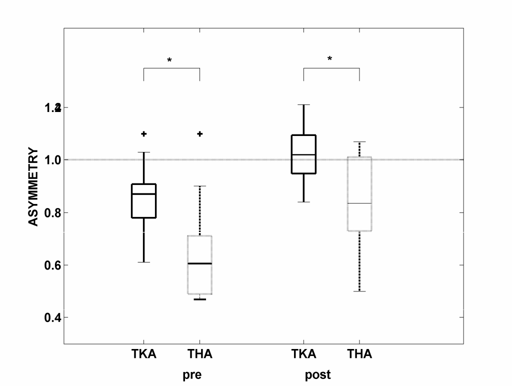

Fig.1 Asymmetry data; THA(=dotted box) TKA (=solid box), line 1=symmetry

CONCLUSIONS: Knee patients use the kinematic strategy to compensate, whereas the hip patients use kinetic compensation. During the rehabilitation period, the therapist should focus on teaching THA patients how to load the prosthetic leg again, because asymmetrical leg loading is a risk factor for development of osteoarthritis in the contralateral leg [2].

ACKNOWLEDGEMENTS: Thanks to Johnson & Johnson, Leeds, UK for their support.

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The recovery after total knee arthroplasty can be hampered by contralateral osteoarthritis

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INTRODUCTION: Total knee arthroplasty (TKA) patients are usually of higher age and often develop comorbidities, which can be confounders in a functional analysis of the knee. Contralateral knee problems are frequently seen as a comorbidity in ostheoarthritic patients [1]. In the past, we have described the sit-to-stand movement (STS) as an adequate test to measure the functional knee status of TKA patients [2]. In this study, we performed a kinetic and kinematic analysis of the STS of TKA patients to assess the influence of contralateral osteoarthritis on the functional recovery of TKA patients.

METHODS: A group of 21 TKA patients was measured pre-, 6 months and 1 year postoperatively. After the follow-up period they were divided in a group without contralateral knee problems (sound group) and a group with contralateral knee problems (comorbidity group), based on clinical records. They all received a Press Fit Condylar Sigma system (DePuy, Leeds, UK). A healthy control group (n=27) was matched. The measurements consisted of 10 STS movements from 90° knee flexion. Knee extension angular velocity (VELOCITY_KNEE) and asymmetry (ASYM) were measured during STS, and were the means of 10 trials for one patient. VELOCITY_KNEE was measured with sets of bi-axial accelerometers and gyroscopes on lower and upper leg [3]. Asymmetry was measured with 2 force-plates and quantified equal leg loading:

$$ASYM = \frac{Peakforce\_prosthesis}{Peakforce\_contralateral}$$

The asymmetry was compared to a value of 1 (=perfect symmetry).

RESULTS: Postoperatively, the sound group showed a normal VELOCITY_KNEE (p=0.06, see fig 1), whereas the comorbidity group still showed an inferior knee extension velocity compared to the control group (p=0.001). The sound group showed asymmetry preoperatively (see fig 2), and improved to a symmetrical STS after 1 year follow-up (p=0.56). The comorbidity group, however, showed no asymmetry pre-, nor postoperatively (p=0.14), although there was a trend to (over) loading of the prosthetic leg.

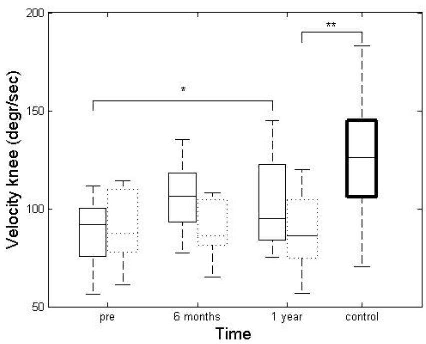

Fig.1 Boxplot of VELOCITY_KNEE
Sound (=solid box) and comorbidity (=dotted box),
Dotted line in ASYM equals perfect symmetry

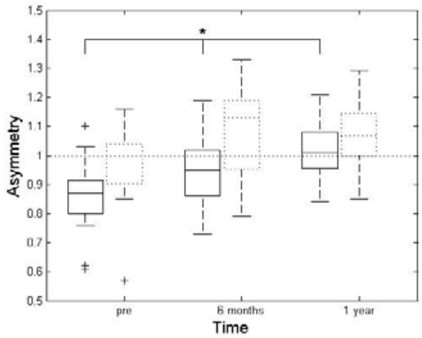

Fig. 2 Boxplot of ASYM *significant improvement (p<0.05), ** significant difference (p<0.05)

CONCLUSIONS: Development of contralateral osteoarthritis can be a confounder of knee function measurement after total knee replacement. The STS measurement can detect contralateral deficiencies; lack of asymmetry preoperatively and lower leg extension velocities postoperatively can be indications of contralateral osteoarthritis.

ACKNOWLEDGEMENTS: Thanks to Johnson & Johnson, Leeds, UK for their support

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Static and dynamic posture in elderly women with hallux valgus practicing physical activity

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INTRODUCTION: Researchers in the last 10 years gave importance to physical activity as a way to develop a good life style and for preventing postural disease [1]. The aim of this study was to verify how hallux valgus pathology modify static and dynamic posture and gait parameters in non sedentary elderly women, and if specific proprioceptive exercises can produce significant changes [2].

METHODS: We recruited 120 moderately active Italian subjects (65 to 75 years old) [3]. We identified 2 different groups, HV: with hallux valgus (first metatarsal joint angle > 15 deg.) and normal: without (< 15 deg.). Each group was divided into 2 sub-groups, depending on the exercises program: A) 2 lessons of physical activities a week, and B) 2 lessons of physical activities a week plus 1 lesson with specific proprioceptive exercises. The activity was done for 4 months for each subject. At the beginning and at the end of this study, participants were required to walk over an Electronic Baropodometer by Diagnostic Support (Italy), with a 120 cm long pressure plate with 4800 sensors. We tested static posture (eyes open and closed) and gait. The parameters extracted were: mean foot pressure distribution (in each foot region), in static posture and gait, stabilometric indexes in posture, total single support time and double support time in gait.

RESULTS: Before specific training – HV subjects, in both static posture and gait, showed a mean foot pressure mainly concentrated in the anterior medial part of the foot, in particular under the 1st metatarsal joint. In gait, both step length and double support duration were longer than in normal subjects while total single support time was shorter. Stabilometric indexes (mean velocity, sway ellipse area, path length) all showed to be significantly (p<0.05) lower for HV group in both eyes open or closed conditions. After 4 month of specific training – mean foot pressure for HV subjects was more uniformly distributed under the foot in both static posture and gait. In particular the variation was significant (p<0.05) when considering all the 6 zones, and not only the area under the 1st metatarsal joint. Total single support time is shorter while no appreciable differences are shown in stabilometric parameters. Our specific exercise program doesn't create modifications in the parameters in normal subjects. On the other side for the HV subjects of group A the differences with normal group becomes more relevant.

CONCLUSIONS: Our results illustrate the greater pressure on 1st metatarsal joint as a persistent condition in static and dynamic posture in HV participants, being body weight mainly distributed in the medial - frontal part of the foot. In gait pattern, we noticed a longer step length related to a shorter total single support time, but also a longer double support time. This may reflect a strategy for HV subjects in double support for searching stability during the gait or a lack in the push off power by toe's muscles. Stabilometric data may reveal a stiffening of the trunk which may result as a strategy to compensate for a decreased contribution of foot proprioception on postural stability. The first one determines a decrease of the resistance to the effort and increases the damage of the joint caused by chronic micro shock, and may lead to vascular pathology. After the training, the foot pressure increases in posterior and lateral part of feet and this is significant in global feet evaluation. Results showed that activity reduces the increment of pathological situation showed in the inactive group, obtaining an important conservative result for our specific training exercises.

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Differences in proprioceptive postural control during the sit-to-stand-to-sit movement between persons with non-specific low back pain and healthy controls on a stable surface

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INTRODUCTION: Persons with non-specific low back pain (NSLBP) have been observed to have an altered postural control strategy during static postural conditions (e.g. quiet standing), due to decreased reliance on lumbosacral proprioceptive inputs [1]. It remains unclear whether persons with NSLBP show an altered proprioceptive control strategy during more dynamic postural tasks. Therefore, the aim of the present study was to examine the performance of a sit-to-stand-to-sit task (STSTS) on a stable support surface in persons with NSLBP and healthy controls.

METHODS: The total duration of five consecutive STSTS movements as well as the duration of each stance, sitting and movement phase of 47 young subjects with NSLBP and 9 young pain-free subjects was recorded. Postural sway characteristics were evaluated with a six-channel force plate during the five consecutive STSTS movements. In addition, muscle vibration on triceps surae muscles and lumbar multifidus muscles was used to appraise the relative proprioceptive weighting (RPW) [1]. A score equal to 1 corresponds to 100% reliance on afferent input from triceps surae muscles for postural control, a score equal to 0 corresponds to 100% reliance on back muscle afferent input.

RESULTS: Persons with NSLBP need significantly more time to perform five consecutive STSTS movements compared to pain-free subjects ($p<0.005$). This longer performance is mainly caused by longer stance phases ($p<0.05$), while the durations of the sit-to-stand, the stand-to-sit movements and the sitting phases are not significantly different between the people with NSLBP and the healthy controls ($p>0.05$). Furthermore, the postural sways during the stance phases are significantly larger in persons with NSLBP compared to the healthy controls ($p<0.05$). In addition, persons with NSLBP have significantly higher RPW values in comparison with the healthy persons (NSLBP: 0.71 ± 0.17; Healthy: 0.51 ± 0.15; $p<0.05$).

CONCLUSIONS: The adopted proprioceptive postural control strategy (i.e. more ankle-steered vs. multi-segmental control observed in healthy persons) in people with NSLBP seemed to have a negative effect on the performance of a dynamic postural task such as STSTS. A task of *associated movements* or *anticipatory postural adjustments* is to maintain postural stability during movements with high acceleration or mass displacement [2]. Therefore, the observations of the longer duration of the stance phases and the concomitant larger sways suggest mainly impairments in anticipatory postural adjustments and not in the focal motor program in persons with NSLBP. Moreover, the control of pelvic movement in the process of mass redistribution during trunk movement is normally highly efficient, however, this proprioceptive control of the pelvis may be impaired in these subjects with NSLBP [2,3]. Further study with direct measurement of pelvis kinematics is needed to underscore this hypothesis.

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Differences in proprioceptive postural control during the sit-to-stand-to-sit movement between persons with non-specific low back pain and healthy controls on an unstable support surface

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INTRODUCTION: It has been demonstrated that persons with non-specific low back pain (NSLBP) exhibit a rigid postural control strategy in static circumstances (e.g. quiet standing), even in postural conditions when this ankle-steered strategy is not the most appropriate such as standing on an unstable support surface [1]. It remains unclear whether this altered postural control strategy is used in more dynamic tasks on unstable support surfaces. Therefore, the aim of this study was to examine the differences in proprioceptive postural control strategy during the sit-to-stand-to-sit (STSTS) movement on an unstable support surface ("foam") in people with NSLBP and healthy controls.

METHODS: The total duration of five consecutive STSTS movements performed on "foam" as well as the duration of each stance, sitting and movement phase of 47 young subjects with NSLBP and 9 young pain-free subjects was recorded. Postural sway characteristics were evaluated with a six-channel force plate during the five consecutive STSTS movements. In addition, muscle vibration on triceps surae muscles and lumbar multifidus muscles was used to appraise the relative proprioceptive weighting (RPW) [1]. A score equal to 1 corresponds to 100% reliance on afferent input from triceps surae muscles for postural control, a score equal to 0 corresponds to 100% reliance on back muscle afferent input.

RESULTS: Persons with NSLBP need significantly more time to perform five consecutive STSTS movements on an unstable support surface than pain-free subjects ($p<0.005$). This longer performance is caused by both longer stance phases ($p<0.05$) and longer sitting phases ($p<0.05$), while the sit-to-stand and stand-to-sit movements have equal durations in people with NSLBP and healthy controls. Furthermore, the postural sways during the stance phases are significantly larger in persons with NSLBP compared to healthy controls ($p<0.05$). In addition, persons with NSLBP have significantly higher RPW values compared to healthy controls on an unstable support surface (NSLBP: 0.49±0.19; Healthy: 0.38±0.12; $p<0.05$).

CONCLUSIONS: Despite the adoption of a more multi-segmental proprioceptive postural control strategy (still less than the healthy controls) during the unstable support surface condition, these young persons with NSLBP still seemed to have more problems performing a dynamic postural task such as STSTS. For the performance of complex postural tasks optimal co-ordination of producing mobility while also preserving stability is necessary [2,3]. However, the persons with NSLBP showed longer durations of both the stance and sitting phases and larger sways during standing, indicating mainly impairments in the preparatory postural adjustments but not in the focal movement. Preparatory postural adjustments via pelvic control might be impaired in these persons with NSLBP. Further research will be required to elucidate the role of proprioceptive control of the pelvis in complex axial movements and ultimately in the mechanisms of NSLBP.

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Low back pain associates with altered activity of the cerebral cortex prior to arm movements that require anticipatory postural adjustments of the trunk

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INTRODUCTION: Low back pain (LBP) represents a common and costly health care concern, with high rates of recurrence and chronicity that suggest ineffective treatment for a large number of patients. Changes in central postural control have been associated with chronic LBP, but the mechanisms of these changes in control remain unidentified. It thus remains necessary to determine whether chronic LBP associates with altered postural stabilization and concomitant changes in motor neurophysiology in order to inform more directed rehabilitation strategies.

METHODS: Ten participants with LBP and 10 participants without LBP performed self-initiated, rapid, voluntary arm raises. Electromyographic onset latencies of the bilateral internal oblique and erector spinae muscles were analyzed relative to the onset of the deltoid muscle as measures of anticipatory postural adjustments (APAs). Amplitudes of alpha event-related desynchronization (ERD) and of Bereitschaftspotentials (BP) were calculated from scalp electroencephalography as measures of cerebrocortical neurophysiology related to motor preparation.

RESULTS: Significant ($P < 0.05$) alpha ERD was evident bilaterally at the C3 and C4 electrodes for participants with LBP but only at the midline Cz electrode for those without LBP (electrodes that overlie somatotopically distinct regions of the motor cortex). The group with LBP, on average, exhibited delayed APA latencies and larger BP amplitudes than the group without LBP, but these differences were not statistically significant ($P > 0.05$). Larger BP amplitudes, however, significantly correlated with earlier APA onset latencies for participants with (but not for those without) LBP. Participants with LBP exhibited significantly less variable APA onset latencies than the participants without LBP.

CONCLUSIONS: Preparatory motor activity of the cerebral cortex and APA timing becomes altered prior to rapid arm movements for individuals with chronic LBP. These results support a theoretical model that altered central motor neurophysiology associates with LBP, thereby implying that rehabilitation strategies should address these neuromotor impairments.

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3D knee joint symmetry during walking on various inclines before and after ACL reconstruction: application of an inertial-based system

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INTRODUCTION: During the past two decades, numerous studies were conducted to analyse the change of knee joint function after anterior cruciate ligament (ACL) rupture and reconstruction [1, 2]. Most of these studies were realized inside a dedicated laboratory and considered only few steps in level walking. Recently, an inertial-based system was proposed to measure the three dimensional (3D) angle of the knee joint [3]. This system can be used outside a laboratory and thus easily allows unconstraint gait analysis. The aim of this study was to show the efficiency of this system to analyse the 3D function of ACL-deficient knee joints before and after reconstruction.

METHODS: Five young patients with an isolated ACL rupture took part at three gait analyses: before and two times (5 and 14 months) after reconstruction. The 3D knee joint angles were measured over several meters for three inclines (level, as well as uphill and downhill at 3.5%) using an ambulatory system (Physilog®, CH). The 3D angles were calculated for each cycle following [3] and then averaged over each trial. Finally, the 3D pathologic and controlateral cycle patterns were compared using a modified symmetry index (MSI). This index expresses the absolute area between both patterns in percentage of the mean (pathologic and controlateral) range of motion.

RESULTS: According to clinical scores, the knee joint functions were comparable to the literature for the three analyses. Figure 1 presents the MSI of the five patients for the three knee joint angles (FE: flexion/extension, AA: abduction/adduction and IE: internal/external rotation) before and after surgery. Similar tendencies were noticed for the three inclines. In FE and IE, an increase of the symmetry (closeness to zero value) was noticed at both follow-ups. In contrary, no change was observed in AA.

CONCLUSIONS: Symmetry of ACL-deficient knee joints was evaluated using a novel inertial-based system. The tendencies for level walking were in good agreement with previous studies and showed changes not only in FE, but also in IE [1, 2]. Moreover, the results obtained for the two other inclines confirmed these tendencies. Other patients will soon realized the third analysis and thus complete these preliminary results.

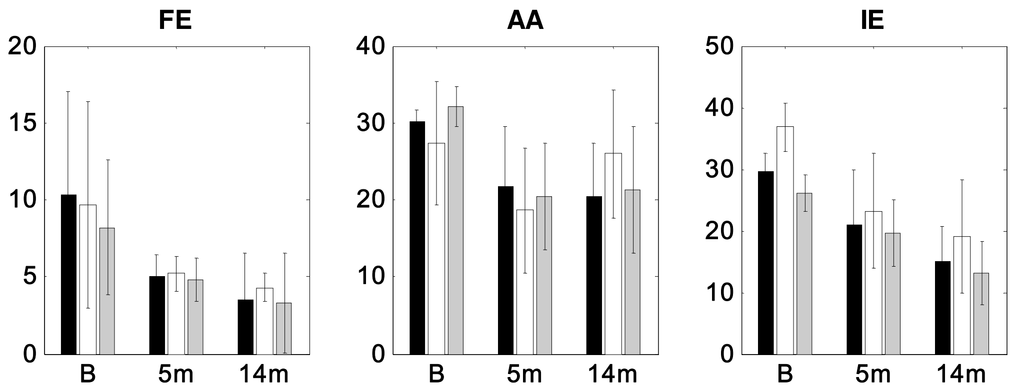

Fig.1 Mean and standard deviation of the 3D MSI obtained for the five patients before (B), 5 months (5m) and 14 months (14m) after reconstruction. Black, white and gray bars correspond respectively to level, uphill and downhill walking

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Posture analysis of patients with ankylosing spondilytis

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INTRODUCTION: Ankylosing spondylitis (AS) leads to total immobility of the spine and a fixed kyphosis may appear. From a biomechanical point of view, the spinal kyphosis causes a forward and downward shift of the centre of mass (CoM) of the trunk in the sagittal plane. Extension of the hips, flexion of the knees and plantar flexion of the ankles may counterbalance the forward shift of the body CoM relative the base of support [1]. Even if evidence suggest that a rigid spine may cause problems with balance and weight distribution, in literature [2] there are less quantitative measurement data on balance in AS patients. The aim of this study was to quantify balance in AS patients in 7 different posture assessments, with a sterophotogrammetric system together with a force plate.

METHODS: We included 8 patients with AS (as the definition of New York Criteria); a clinical assessment on each subject was performed, including clinical profile and measures of motor function. A modified version of the protocol presented in [3] was adopted which entails of the inclusion of 3 extra markers on the heads: glabella, right and left temporomandibular joints. The subjects were asked to stand for 60 seconds in an upright position with the feet 30° apart and their arms along the body. The data collection was realized with a modified version of [4]; so far, the subjects were instructed to look at a small achromatic circular target placed about 1 meter from the eyes, at 7 different heights: eye height, ±10°, ±20°, ±30° than eye level.

RESULTS: At clinical assessment each patient displayed an increment in the thoracic kyphosis (>40°) with an anterior protrusion of the head and a decreased neck range of motion. Every subject, except one, revealed a trend toward reduction (Fig. 1) either in every measures of centre of pressure (CoP) trajectory over the support surface, or the area covered by the CoP and the CoP sway. Furthermore in every subject, except one, the kinematic analysis showed hip, knee and ankle flexion strategy. We observed the major grade of destabilization in posture when the subjects stare a fixed point at 20° higher and lower than eye level.

CONCLUSIONS: Our study highlighted in AS patients an altered posture and decreased range of motion which are generally associated with balance impairment. So far they adopted different strategies to maintain their balance in relation with their passive range of motion. The subject with a different trend in both the posturographic and kinematics parameters, exhibited difficulties in maintaining the standing posture during the static trial (no clinical visual or vestibular pathologies were documented).

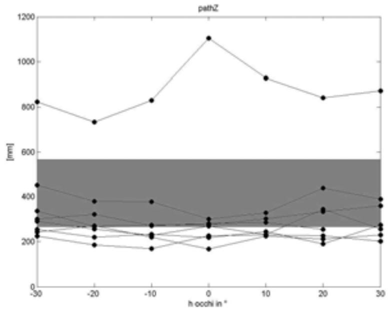

Fig.1 Anterior-posterior displacement of CoP (gray=normative bands).

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Vertical heterophoria, postural control and chronic back pain

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INTRODUCTION: Clinical observations reported a link between vertical phoria, chronic pain and qualitative balance test [1]. The aim of the study was to test the quality of postural performance in quiet upright stance in healthy young adults with vertical heterophoria (VH) - relative deviation of the visual axes reduced via binocular vision mechanisms - within the physiological range or without VH (i.e. vertical orthophoria, VO).

METHODS: Twenty six healthy young subjects (mean age: 27.04±3.29 years) were recruited. The postural stability was measured on a force platform while the subjects fixated a target at eye level in a straight ahead position, placed at either 40 or 200 cm.

RESULTS: The results indicated that the postural stability was better for subjects with VO than subjects with VH. Particularly we found an interaction between vertical phoria and distance: the subjects with VH show greater instability than the subjects with VO at a far distance. An additional study showed that the cancellation of VH with a prism improved postural stability healthy young adults. Therefore, the quality of postural performance in quiet upright stance was lower in the subjects with VH. Another ongoing study examines patients with chronic back pain (in the absence of neuropathy, rheumatism or repetitive strain injury) associated with VH. The magnitude of VH is measured and a prism is applied to cancel it. Postural control while fixating at near or at far is measured with or without the prism. Preliminary results show improvement of postural stability with the prism, particularly at far distance.

CONCLUSIONS: We speculated that VH even when small in size, indicated a perturbation of the somatosensory/proprioceptive loops involved in postural control [2]. We suggest that VH could reflect a mild global sensorimotor conflict between sensory and motor inputs i.e. a non optimal integration of the various signals. Poor integration of somaesthetic cues could affect the quality of the balance control and lead to pain. This is in line with the experimental model introduced by McCabe et al. [3] providing evidence that sensorimotor conflict can induce pain and modify sensory perception in some normal subjects. Perhaps functional chronic back pain results from such prolonged conflict.

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P.110

An active pain episode is associated with hypermetric automatic postural responses in individuals with chronic, recurrent low back pain compared to those without low back pain

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INTRODUCTION: Individuals with chronic low back pain demonstrate altered movement strategies that may result from changes in neuromuscular control. However, whether these movement strategies are a cause or a consequence of pain has yet to be determined. The purpose of this study was to compare the movement strategies, as measured by joint torque responses, elicited by systemic, unexpected perturbations in 3 cohorts; individuals with LBP in quiescent vs. active periods of pain and individuals without LBP.

METHODS: 21 subjects without LBP (NLBP; 33±10.5 yrs), 20 subjects with a history of chronic, recurrent LBP but in a quiescent period of pain (qLBP; 39.9±14.9 yrs) and 17 subjects with a history of chronic, recurrent LBP but in an active period of pain (aLBP; 40.2±7.8 yrs) were instructed to stand with feet on separate force plates mounted on a moveable platform that was translated unexpectedly in one of 12 directions. Forces, 3-D body kinematics and anthropometric data were used to calculate net frontal and sagittal plane torques at the ankle, knee, hip and trunk using inverse dynamics. Torque integrals representing both passive (50-100ms post-perturbation) and active (100-300ms post-perturbation) torque production time periods were analyzed with a mixed model, repeated measures analysis of variance design (Group by Direction).

RESULTS: Altered joint torque responses were demonstrated at both distal and proximal joints following perturbations, although statistical differences were more consistently detected in the sagittal plane. During the passive period, the qLBP cohort did not differ from the NLBP cohort, while the aLBP group did demonstrate altered responses (p ranged from <0.01 to 0.05) often demonstrating either increased torque or altered torque polarity compared with the other groups (i.e. flexion vs. extension). In general, individuals with active pain (aLBP) demonstrated hypermetric joint torque responses during the active period at the ankles, knee and hips, compared to both the NLBP and qLBP groups (p ranged from <0.01 to 0.05), with hypometric joint torque production at the trunk (p < 0.01). These altered responses were largely limited to the sagittal plane, particularly following anterior perturbations that induced backward body sway. In the frontal plane, torque responses, particularly at the trunk demonstrated left vs. right asymmetries in the aLBP relative to both the NLBP and qLBP groups.

CONCLUSIONS: The hypermetric joint torques distally and hypometric trunk torque demonstrated by the aLBP group suggest that pain exerts an immediate impact on automatic postural coordination, possibly influenced by altered central set that aims to reduce the torque produced at the locus of pain. This torque reduction may necessitate increased distal torque production in order to successfully respond to the balance perturbations. The absence of significant differences in both passive and active torque responses between the qLBP and NLBP groups suggest that in the absence of pain, automatic postural responses tend to return to more normal magnitudes. Alternatively, the lack of differences between the qLBP and NLBP groups could indicate that the torque analysis is not sufficiently sensitive to detect the altered motor coordination that has been shown to persist following resolution of an active pain episode [1].

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Decreased modulation of force responses to multidirectional surface perturbations from individuals in an acute flare-up of low back pain compared to those in a quiescent pain phase or those without pain history

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INTRODUCTION: Low back pain (LBP) has been associated with abnormal anticipatory and reactive postural strategies that persist even in the absence of lumbar pain. To better guide rehabilitation of this population, it is important to quantify postural impairments in different pain states to attempt to understand the potential contribution of these impairments to the persistence of LBP. The purpose of this study was to compare the automatic postural responses (APRs) of individuals without LBP to those of individuals with a history of recurrent LBP who were either in a quiescent period or an active flare-up.

METHODS: Three subject groups were recruited from the community: nLBP, comprised of 22 control subjects (14 females, 32 ± 10 yrs of age) without LBP; qLBP, comprised of 25 subjects with chronic, recurrent LBP of longer than 6 months (12 females, 39 ± 13 yrs), but in a quiescent period of pain; and aLBP, comprised of 39 subjects (20 females, 41 ± 8 yrs) seeking physical therapy for an acute flare-up of LBP. Subjects responded to three trials of support surface translations in each of 12 randomly presented horizontal directions. Subjects were asked to assume their natural self-selected stance width and toe out angle with each foot placed on a separate force plate. The magnitude of the horizontal force vector (square root of $Fx^2 + Fy^2$) under each foot was determined for two intervals from 50 – 100 ms and 100 – 300 ms after perturbation onset. The resultant forces in the two different time intervals were analyzed with a mixed-model ANOVA to determine differences in the force responses among the three groups and across the 12 directions of surface translation. A *P* – value of 0.05 or less defined a statistically significant difference.

RESULTS: The three groups were not significantly different with regard to height, gender, or body mass index (P > 0.05). The aLBP group reported higher ratings of pain than the other groups, as determined by the McGill Pain Questionnaire (P < 0.02) and the Numeric Pain Rating Scale (P < 0.01). The nLBP and qLBP groups exhibited force responses that were directionally tuned and modulated across all translation directions during the 100 to 300 ms time interval (P< 0.01). The aLBP group, however, exhibited more similar force responses across the directions of perturbation compared to the nLBP and qLBP groups (group * direction, P < 0.01), due to a significantly decreased horizontal force response to forward perturbations that induced backward body sway.

CONCLUSIONS: In contrast to the nLBP and qLBP groups, the aLBP group did not demonstrate directionally tuned horizontal force responses, which may be due to a decrease in active muscle recruitment or to altered muscle synergy selection. The decrease in horizontal force magnitude may reflect an attempt to decrease trunk motion and trunk torque, particularly in response to forward perturbations, which could potentially provoke lumbar pain. The increased lumbar pain of the aLBP group appears to alter the horizontal forces of the APR in a manner not evident from the qLBP group, although other changes to the APR have been reported to persist during quiescence despite the reduction in lumbar pain [1]. Thus, impairments of reactive postural control should be addressed during rehabilitation of both acute and chronic low back pain.

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Symmetry of ground reaction forces in patients with total knee arthroplasty

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INTRODUCTION: Previous research has demonstrated dramatic improvements in gait following knee replacement surgery for treatment of moderate and severe osteoarthritis [1]. Persistent gait asymmetry, however, has been associated with development of osteoarthritis at other joints following knee replacement, most prevalently at the contralateral knee [2]. The purpose of the current study was to examine symmetry of ground reaction forces during gait before and after knee replacement surgery.

METHODS: Gait assessments were completed twice prior to surgery (1 month and 1 week pre-surgery), and at 1, 3, 6, 9, and 12 months post-surgery. Data are presented for 4 patients who have completed at least the 3 month evaluation. Participants completed 20 walking trials along a 7 meter path, during which they stepped on consecutive embedded force plates with the left and right feet during steady state gait. Ground reaction forces (GRF) were sampled at 50 Hz, and filtered offline at 12 Hz. Peak vertical, anteroposterior (AP), and mediolateral (ML) forces were calculated. Symmetry of ground reaction forces in each direction was calculated as (unaffected limb / affected limb; perfect symmetry=1.0).

RESULTS: AP GRF (Figure 1) was symmetrical prior to surgery, during the braking (1.03) and propulsive (1.00) phases of foot contact. AP braking GRF was asymmetrical at 1 month (0.92) and 3 months (0.90) post surgery; the affected limb demonstrated relatively larger forces at these time points. AP propulsive GRF was asymmetrical at 1 month (1.12) post surgery with greater forces exerted by the unaffected limb. ML GRF (Figure 2) was asymmetrical pre surgery (0.80), and at 1 month (0.74), and 3 months (0.70) post surgery; the affected limb demonstrated relatively larger forces at these time points. Vertical GRF was symmetrical both prior to and following surgery.

CONCLUSIONS: Larger braking forces observed in the AP direction following surgery may be indicative of an inability to provide sufficient absorption through the kinetic chain. Asymmetry of propulsive forces in favour of the unaffected limb at 1 month post surgery suggest that patients reduce the propulsive force generated by this limb, possibly related to habitual walking behaviours or issues of confidence in the affected knee joint. Persistent and worsening ML GRF following surgery may be associated with abnormally small ML shear forces in the unaffected limb, to reduce COM movement toward the affected limb. Alternatively, ML GRF asymmetry may be associated with a globally altered gait pattern, for example, a “waddling gait”. ML GRF asymmetry may be associated with persistent balance dysfunction following knee replacement surgery.

ACKNOWLEDGEMENTS: Canadian Orthopedic Foundation, Canadian Foundation for Innovation, York University, Toronto Rehabilitation Institute, and Ontario MOHLTC.

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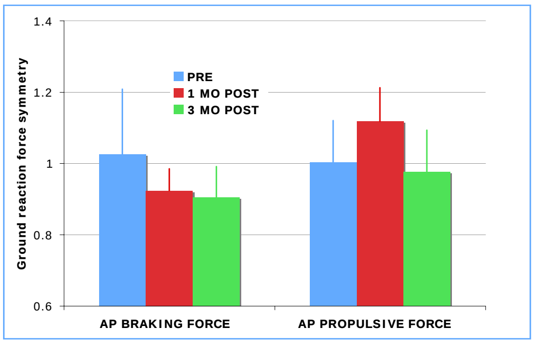

Fig. 1 GRF symmetry in AP direction

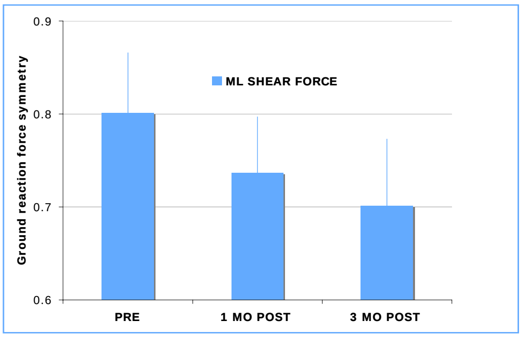

Fig 2: GRF symmetry in ML direction

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Does the Genu valgum phenomenon lead to a modification of stabilometric results?

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INTRODUCTION: The normalization of stabilometric measurements on the force platform indicate that the feet are positioned using a guide with an open angle of 30° between the two heels placed 2cm apart. In subjects affected by Genu valgum, this position generates inter-femoral contact likely to reduce the independence of movement of the lower limbs [1]. We have carried out research to discover whether this method of measurement is likely to induce erroneous stabilometric results.

MATERIALS AND METHODS: Surfaces and the mean values of X and Y of all patients with Genu valgum with 5cm were measured systematically on a force platform with a standardized foot guide and with eyes open. The same subjects were then re-measured with a foot guide adapted with a base of 5cm (sample P). This sample was compared with a control sample unaffected by Genu valgum (sample N).

RESULTS:

Sample P (18 subjects)	Sum of values of Surfaces	Sum of X values	Sum of Y values
2 cm wedge, EO (standard)	5,681 mm^2	157.3	528.4
5 cm wedge EO	3,805 mm^2	157.9	439.8
Variations	1,876 mm^2	0.6	88.6
Percentage of variations	49.3%	0.3%	20.1%

Sample N (18 subjects)	Sum of values of Surfaces	Sum of X values	Sum of Y values
2 cm wedge, EC (standard)	3,104 mm^2	134.5	397.6
5 cm wedge EC	3,486 mm^2	153.4	380.1
Variations	382 mm^2	18.9	17.5
Percentage of variations	10.9%	12%	0.4%

DISCUSSION, CONCLUSION: The interposition of a 5 cm wedge does not appear to significantly modify the posturographic data in subjects unaffected by Genu valgum. In subjects presenting Genu valgum with an intermalleolar space greater than 5 cm the use of the wedge leads to a significant reduction in the SKG surface parameter of the order of 49.3% and a modification of the mean position of the CoP in the proportion of 20.1% in the Y axis. These discoveries appear to show that failure to use a foot guide adapted to the subject produces erroneous posturographic data [2].

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P.114

Walking outdoors or treadmill – What is preferable in post-stroke rehabilitation?

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INTRODUCTION: The principal aim was to evaluate treadmill training versus walking outdoors for improvement of step length, step width, cadence, walking speed and distance in walking. A secondary aim was to compare the outcomes in relation to length of time exercising and number of exercise occasions between the two.

METHODS: A randomised controlled trial at a recreational center. Inclusion criteria were neurological impairment and age above 50 years. Exclusion criteria were barriers to taking part in a physical rehabilitation programme, insufficient language, an unstable cardiac status, neurosurgery and a pre-morbid history of orthopedic problems or any problems that would prevent patients from walking. The group participating in the treadmill exercises was planned to do a maximum 30 minutes 5 days a week for the period the patients were at the recreational centre. The treadmill had hand railings to hold on to, otherwise there were no safety precautions or body support. Walking outside was performed in a comfortable speed and with the use of ordinary assistive devices when necessary. The walk was depending on time rather than length, and the intention was a 30 minutes minimum walk. Outcome measures were: 6-Minute Walk Test and a 1o-metre walk test, performed with markers on the heels on both feet, to measure step length, stride length and step width, from this cadence was calculated. The walk - way was 14 metres long, with 2 metres for warming up and 2 metres for slowing down. Gait speed was measured with a stop-watch.

RESULTS: A total of 39 persons with stroke (treadmill group n=18, walking outdoors n=16) were included; five persons dropped out. Time after stroke was 480 days in the treadmill group and 300 days in the outdoor walking group. There were no baseline differences between the groups and length of stay was approximately 2.5 weeks, mean age 75 years in each group, and hemisphere lesion was mainly on the right side in both groups. All participants were active in their respective programs and compliance to the program was 100%. Frequency of exercise was not different between the groups (9 versus 11, p=0.43) but the amount of time exercising on the treadmill was significantly less than time spent doing walking exercise outdoors (107 versus 316 minutes, p=0.002). This difference in time influenced significantly between the groups on walking speed (6MWT, p=0.01, 10m, p=0.009), distance (6MWT, p= 0.01) and step length (right leg; p=0.09, left leg; p=0.07) but not in step width (p=0.45) or cadence (p=0.12). Step length on the left leg improved to a higher degree in the treadmill group than in the walking outdoor group indicating a more symmetrical use of the legs in the treadmill group (1.02 to 1.10 versus 0.97 to 0.96). There were no differences in use of assistive aids between the groups on arrival to the clinic or at departure.

CONCLUSIONS: This study aimed at evaluating treadmill training versus walking outdoors regarding qualities in gait: bilateral step length, step width, cadence, walking speed and walking distance. The results indicate that treadmill walking and walking outdoors both improve these qualities and that both types of exercise are feasible within the recreational setting. Treadmill walking, however, achieved this improved function in less time and, regarding bilateral step length, with a higher degree of symmetrical use.

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Enhancing walking in people with incomplete spinal cord injury by improving swing phase activity: a pilot randomized controlled trial

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INTRODUCTION: Almost half of all spinal cord injuries result in motor-incomplete lesions meaning that there is some preservation of motor function below the level of injury. The recovery of walking is possible after motor-incomplete spinal cord injury, particularly with intensive, task-specific gait training. In recent years, there has been a great deal of attention on treadmill training with partial body weight support as a means of providing task-specific training of walking. While positive outcomes may be realized, there are continued deficits in functional ambulation, such as slow gait velocity and difficulty in clearing obstacles. Such deficits may be associated with inadequate flexor muscle activity during the swing phase. Most of the research on rehabilitation interventions designed to overcome deficits in flexion have focused on external aids, such as orthoses, or functional electrical stimulation to compensate for weakened or paralyzed flexor muscle activity. However, there has been little research on strategies that may be employed during rehabilitation training to enhance the recovery of flexor muscle activity during walking. The primary objective of this study is to evaluate the effect of a novel treadmill gait training strategy designed to target training of flexor muscle activity during the swing phase of walking. We hypothesize that a treadmill training program, in which resistance against leg flexion is applied, will enhance flexor muscle activation and improve functional outcomes in individuals with motor-incomplete spinal cord injury.

METHODS: Adult participants with chronic (>1 year) spinal cord injury are randomly allocated to a robotic-assisted or robotic-resisted treadmill training intervention. Inclusion criteria include motor-incomplete spinal cord injury (ASIA C or D) and ability to walk on a treadmill with partial body weight support. Treadmill training will be implemented using the Lokomat® (Hocoma AG, Volketswil, Switzerland). The control therapy involves Lokomat training where leg movements are completely assisted using the standard software control of the device. The experimental therapy involves Lokomat training whereby the robot's motors apply a velocity-dependent torque against hip movements. Treatments take place 3 times/week for 12 weeks, 45 minutes per session. Outcome variables include overground gait velocity (10-meter walk test), distance covered in 6 minutes (6-minute walk test), functional walking tasks (such as the ability to climb stairs or step over obstacles), and lower limb electromyography and kinematic parameters of gait.

RESULTS: Preliminary results have been obtained from 3 participants. Participants tolerated the modified approach to treadmill training well and showed improvements in their ability to train for longer bouts with fewer rest breaks over the 12-week training period. Preliminary data indicate that there were improvements in overground walking parameters (overground gait velocity, endurance) as well as some of the functional walking tasks such as obstacle crossing and stairclimbing, particularly for the participants in the robotic-resisted group.

CONCLUSIONS: Our results to-date indicate that there are promising effects of this modified approach to treadmill training, particularly for individuals who have already attained a basic level of gait function. Ongoing data collection will confirm and extend these findings to determine whether improvements in muscle activity and kinematic gait patterns are associated with improved functional ability in everyday walking tasks.

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Effects of gait training with body weight support system on ground level for stroke patients

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INTRODUCTION: Gait recovery is one of the main goals of rehabilitation programs for stroke individuals. Among different strategies adopted to reach this goal, body weight support (BWS) systems on treadmill have demonstrated to be efficient [e.g. 1-3]. Due the differences between treadmill and ground level walking, we investigated the effects of BWS training on ground level in chronic stroke hemiparetic individuals. More specifically, we analyzed temporal-spatial gait parameters and segmental angles of these individuals during walking on ground level before and after the training.

METHODS: Twelve hemiparetic individuals (eight male and 4 female) with a mean age of 53.17 years were trained 45 minutes, three times a week, during six weeks with 30% of BWS on ground level (Fig. 1). Before and after the training sessions, these individuals were videotaped walking freely on a 10 m walkway three times, in order to obtain kinematic measurements. Passive reflective markers were placed on both sides of the head of fifth metatarsal, lateral malleolus, lateral epicondyle of the femur, greater trochanter, and acromion. The positions of these markers in the video were later digitized using APAS software (Ariel Dynamics, Inc.). One gait cycle per trial was selected for analysis, and the following variables were investigated: step length, stride length and speed, durations of initial and final double limb support and single support, minimum and maximal segmental angles (foot, shank, thing, and trunk) of paretic and nonparetic sides, and mean walking speed.

RESULTS: After the gait training sessions with BWS on ground level, the hemiparetic individuals walked faster, with symmetrical steps, and with longer and faster strides. There were no changes for the durations of support periods, which remained different between paretic and nonparetic sides. Minimum angle of foot and shank and maximum angle of thigh increased during the gait stride. However, the differences between paretic and nonparetic sides for all segmental angles remained.

CONCLUSIONS: Gait training with BWS on ground level might be a safe and promising approach for gait recovery of stroke individuals and can be an alternative strategy for gait training of chronic hemiparetic individuals.

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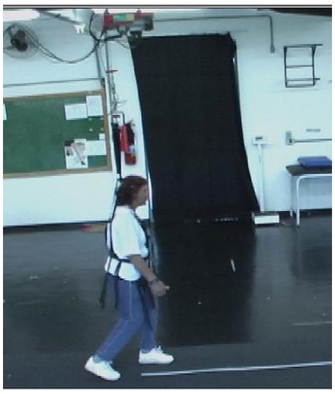

Fig.1 Partial view of the BWS system used during the gait training sessions

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Study of effect of Lokomat training on the expression of the circumduction gait strategy in patients after stroke

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INTRODUCTION: Gait recovery in patients after stroke is the major goal of rehabilitation in early and late post-stroke periods. Many patients with post-stroke hemiparesis use the compensatory strategy to achieve foot clearance during swing in the form of circumduction defined as hip hike and abduction of the hip to advance the limb. It is know that this circumduction gait strategy is often observed in patients even when the paresis in lower limb is reduced. Objective: to estimate of the effects of the Lokomat training on the some clinical parameters and on the expression of the circumduction gait strategy in patients after stroke.

METHODS: 77 hemiplegic stroke subjects (mean age 53.6±10.4 years) with mild to moderate lower limb impairments (Motricity index for leg scores 39.33±23.24 and for body – 84.83±19.14) we studied. Stroke inclusion criteria included unilateral lesion of the cortex or subcortical white matter with an onset to the start of the rehabilitation course was 21-101 days (mean 47.2 days). All patients were randomized into 2 treatment groups: the Lokomat group of 57 patients received the complex therapy enclosed the Lokomat training and the control group of 20 patients who received only conventional therapy. In Lokomat group four parameters were adapted to ability, strength, and endurance of the patients: (1) body weight support, set initially at 35.6%±3.7%, was gradually reduced to 5 - 0%; (2) walking duration was increased to a maximum of 45 minutes; (3) mean treadmill speed was initially set of 1.46±0.18 km/h., then gradually increased to a maximum of 1.9±0.17 km/h; and (4) guidance force provided by the Lokomat on the hemiparetic leg was gradually reduced from 100% to 15%. The training course included 10-21 sessions. Patients were assessed before and after the rehabilitation course with the Motricity index for leg and body, Ashworth scale of tone, 10-m timed walking speed. Besides, 10 patients from the Lokomat group were tested with the 3D motion tracking system “Flock of birds” (Ascension Technology Corp.).

RESULTS: After rehabilitation course we noted significant increase in all variables. Motricity index for paretic leg increased at 59.8% and for body – at 16.5%, and Ashworth scale of muscle plasticity decreased for 42.7%. In patients assessed with the “Flock of birds” system we noted the tendency of the decrease of the expression of the circumduction gait strategy in paretic leg.

CONCLUSION: Robotic-assisted walking system Lokomat has positive effect not only on general gait characteristics, but also decreases the intensity of pathological lower-limb synergy, that serves as the main factor for the improvement of quality of gait. Further researches are however needed to study of the effect of the Lokomat training for the prevention of the forming of circumduction gait strategy in the acute and early post-stroke periods of rehabilitation.

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Treadmill gait training with leg loading to improve locomotor performance in chronic stroke patients

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INTRODUCTION: Reduced gait speed and muscle weakness are major consequences of stroke. Gait performance can be improved by task-oriented training such as treadmill gait training in persons with hemiparesis (Van de Port et al. 2007, Am J Phys Med Rehab). However, this training does not specifically target lower limb muscle weakness. Leg loading, such as adding a load at the ankle, has been shown to increase muscle moments and power of the hip flexor muscles during gait in healthy persons (Noble and Prentice, 2006, Exp Brain Res) and knee flexion in incomplete spinal cord injured persons (Lam et al. 2008, Neurorehabil Neural Repair). Consequently, the combined approach (treadmill training + leg loading) might promote even better improvements than treadmill training alone. The purpose of this study was thus to assess the effect of leg loading during treadmill training on the overground gait performance of hemiparetic subjects presenting reduced strength at the hip. The effects of loading were evaluated in a cross-design study comparing treadmill training to treadmill training plus loading.

METHODS: Seven persons with chronic hemiparesis (5 women, 2 men, 60.4 ± 7.9 year old, 7.8 ± 2.9 years post-stroke) were included after informed consent was obtained. They participated in two training periods, separated by 2-3 weeks of rest. Each training period consisted of 12 sessions over four weeks (3 times a week) of 20 minutes of treadmill walking with a progressive increase of gait speed and slope. A load of 1 kg to 1.5 kg was added to the hemiparetic ankle in one of the two four-week training periods, pseudo-randomly (cross-design study). Training effects were evaluated with the following measures: natural and fast gait speeds over 10 meters, the 6-Minute Walk Test (6MWT) and dynamic flexor and extensor hip strength measurements with a Biodex dynamometer at 0° hip flexion during isokinetic tests at 30°/s. These evaluations were performed before, between and after the two training periods.

RESULTS: Over the eight weeks of training, natural gait speed increased by 15.6 ± 19.3 % (from 0.66 ± 0.23 to 0,77 ± 0,36 m/s), maximal gait speed by 24.7 ± 19.7 % (from 0.77 ± 0.32 to 0,98 ± 0,52 m/s), and the distance walked during 6 minutes by 19.5 ± 18.2 % (from 243 ± 115 to 287 ± 147 m). Among the seven participants, four increased the distance walked in the 6MWT and their natural gait speed by more than 10% with leg loading compared to only one without loading. Maximal gait speed increased more than 10 % in 3 participants with leg loading and in 4 without loading. At the same time, maximal strength of the hip flexor muscles increased by 10% or more in the participants who increased their gait speed after the leg loading training, but in only one participant after treadmill training alone. Hip extensor maximal strength increased by more than 10% in 3 of the participants who increased their gait speed in both training periods.

CONCLUSIONS: Overall, in participants who increased their gait performance over the complete training, the improvement in natural gait speed and endurance as measured with the 6MWT were larger after the treadmill training with leg loading. This was associated with an increase of maximal dynamic strength in the hip muscles, particularly the hip flexors with leg loading. Further work needs to be done to confirm these results in more subjects and to classify the type of walking impairments in persons with hemiparesis most likely to benefit from such a training approach.

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A body area network with vibrotactile actuation

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Introduction: In the domain of rehabilitation of motor impairment, one of the strategies adopted to train the patient is the provisioning of biofeedback by integrating additional visual, audio and somato-sensory information. Among possible stimulation, use of tactile feedback can help the user to maintain balance and to improve performance in complex motor tasks. We present here a body area network (BAN), therefore wearable, that can be controlled via wireless, which collects data from a pair of pressure insole and to provide distributed vibrotactile feedback, by mean of a set of 6 wearable motors. The BAN implements different typology of stimuli, on the range of frequency (RF) [50-190Hz], directly embedded in the wearable nodes. We present the implementation of stimulation patterns with different spatio-temporal resolution.

Methods: Vibrotactile stimuli (ST) are defined varying amplitude and frequency content on sensitive body locations. Four major kinds of mechanoreceptors are involved applying direct forces [1]; two of them are particularly relevant in biofeedback applications: Pacinian corpuscles, solicited within the RF [40-500Hz], detect external acceleration or vibration and Ruffini endings, stimulated within the RF [100-500Hz], provide buzz-like sensation. Thus, we designed and implemented a BAN, which can supply several sets of ST. Vibrotactile feedback can be tested with different actuators placement (i.e. hand, trunk, foot) on subjects. The first stimuli set (Table 1, ST A:E) furnishes low intensity vibration (I) while the second set (Table 1, ST F:G) produces buzz-like sensations (B); 5 are the intensity levels: very low (V), low (L), mid (M), high (H), very high (W). Stimuli are characterized by duration (T), duty-cycle (DC) and frequency (F); an external radio trigger is in charge of driving the device according to the desired output. For example, if the focus is balance control in quiet stance, the application will extract the Centre Of Pressure (COP) from the pressure map captured by the insoles and will use it to monitor subject sway. Consequently, this information can feed an algorithm that maps the displacement of COP in vibrations, meaningful for the user to improve her/his perception of her/his positioning.

Results: We exploited the possibility to control intensity, frequency and spatio-temporal resolution to implement more complex stimuli. In particular, we defined 4 different spatio-temporal patterns (e.g. applied under the foot, Fig.1): forward (F), backward (B), revolving clockwise (C), revolving anti-clockwise (A). Fig.1(a) shows F patterns with a growing intensity modulation during the propagation from IL to IH.

Conclusions: A low-cost and low-power wireless embedded node able to provide haptic feedback has been developed. It provides a wearable solution enabling a fine and distinguishable tactile bio-feedback. We discussed its use in a feedback loop where the actuation is in relation with the monitoring of parameters collected by sensors, for example a pair of pressure insoles. The wireless BAN can be therefore used in rehabilitation enabling to support users without the need of ambulatory infrastructures.

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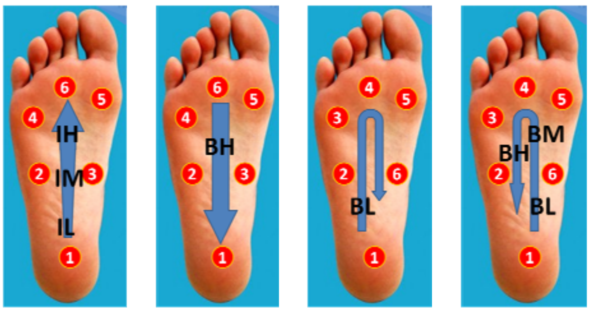
ST	Definition	DC[%]	T[ms]	F[Hz]
A	IV	30	1	50
B	IL	40	1	90
C	IM	60	1	110
D	IH	80	1	130
E	IW	100	1	170
F	BL	30	300	80
G	BM	50	300	110
H	BH	70	300	150

Table 1 Stimuli characteristics



(a) (b) (c) (d)

Fig.1, Example of patterns on the foot plant; red circles show sensors placement

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Healthy elderly are able to learn martial arts fall techniques to reduce hip impact force

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INTRODUCTION: Hip fractures are a serious consequence of falls in the elderly. Important risk factors for hip fractures are osteoporosis and fall mechanics. Hip fracture prevention in clinical practice, however, focuses mainly on the treatment of osteoporosis. Alternatively, hip fractures may be prevented by teaching older individuals how to fall safely. Experimental studies with experienced martial artists [1-2] and healthy young adults [3] indicated that martial arts (MA) fall techniques could reduce the hip impact force. In an MA fall the fall is changed into a rolling movement and the arm is used to break the fall. In older individuals, the usefulness of MA techniques has not been tested yet. Therefore, the purpose of the present study was to determine whether healthy older individuals could learn MA fall techniques and whether this resulted in reduced hip impact forces during sideways falls (thereby reducing the risk for hip fractures).

METHODS: Six male and 19 female healthy older individuals completed a five-session MA fall training. Before and after the training, they performed sideways falls onto a force plate covered with judo mats. The participants started in kneeling position with their right hand holding on to a grip (lean angle 22 degrees). Falls started after a voluntary release of the grip. Kinematic data were collected with a 3D-video system (Vicon) and forces were measured with a Bertec force plate (size: 1.2 by 1.2 m). Two MA experts rated the performance of the falls with a score between 1 (very poor) and 10 (excellent). Fear of falling in daily life was measured with a visual analogue scale (10 cm). To determine the effect of training, paired t-tests were used.

RESULTS: According to the MA experts, fall performance had improved by a mean increase of 1.6 on a ten-point scale ($p<0.001$) after the fall training. In addition, hip impact force was decreased by a mean of 8% (0.20 N/kg*g, $p=0.016$). Fear of falling in daily life as measured with a visual analogue scale was reduced by 27.5% (0.88, $p=0.005$) after training.

CONCLUSIONS: Hence, MA techniques are trainable in older individuals. Furthermore, a better performance leads to a reduced hip impact force and consequently a lower risk for hip fractures. As fear of falling is a predictor of falling [4], the additional reduction of fear of falling in daily life may result in the prevention of falls and related injuries. In future studies, the use of MA falls in daily life and the benefits for hip fracture prevention should be further investigated.

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Contextual transfer of gait adaptation for fall prevention: from moveable platform to slippery floor

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INTRODUCTION: A person's ability to transfer the acquired improvements in the control of center of mass (COM) state stability from laboratory induced repeated moveable platform slips to slip-like perturbations experienced in everyday conditions can have profound theoretical and practical implications for fall prevention; especially, since real-life slips are not constrained to one-degree of freedom.

METHODS: This study investigated the extent to which such contextual transfer could take place. A training group (N=8) initially experienced 24 right-side slips in blocked-and-random order (from the first unannounced, novel slip, S-1 to the last, S-24) resulting from release of a low-friction moveable platform in walking. They then experienced a single unannounced slip while walking on an oil-lubricated vinyl floor surface (V-T). A control group (N=8) received only one unannounced slip on the same slippery floor (V-C). Gait stability was obtained as the shortest distance between the measured center of mass (COM) state (position & velocity) & the mathematically predicted threshold for backward loss of balance (BLOB) at pre-slip touchdown of slipping & post-slip liftoff of contralateral limb.

RESULTS: The moveable platform and vinyl slips had similar kinematic profiles in the A-P direction; however, the former had a significantly lower coefficient of friction than the floor slips. The floor slips had significant lateral displacement and velocity profiles compared to the platform slips. The results demonstrated that the incidence of balance loss and fall on V-T was comparable to that on S-24. In both trials fall and balance loss incidence was significantly reduced in comparison with that on S-1 or on V-C, resulting from significant improvements in the COM state stability.

CONCLUSIONS: The observed generalization indicates that the control of COM stability can be optimally acquired to accommodate alterations in environmental constraints, and it may be broadly coded and easily modifiable within the CNS. Because of such mechanisms, it is possible that the locomotor-balance skills acquired with the aid of low friction moveable platforms can translate into resisting fall encountered in daily living.

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Which part of the forefoot comes closest during swing?

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INTRODUCTION: Tripping is a major cause of falls. During the swing phase of gait, the shoe passes between 1 and 3cm of the ground [1].The proximity of the shoe to ground during this phase creates the risk of an unintentional contact, resulting in a trip fall. For this reason minimal foot clearance (MFC) has been reported in various populations with measurements taken from different points on the shoe e.g. head of first metatarsal or front edge of shoe. Although a shod foot could be regarded as a rigid segment, the different action of tibialis anterior and toe extensors raises the possibility that one part of the shoe comes closer to the ground. Establishing which point on the shoe travels closest to the ground may be valuable for future research and to enhance rehabilitation programmes aimed at reducing trip falls.

METHODS: A convenient sample of fifteen healthy subjects, mean age 33.1 years (SD 10), height 174cm (SD 6.4) and weight 75kg (SD 12.2) were recruited. A three dimensional motion analysis system (Qualysis) was used for all data collection, sampling frequency 50Hz. Three tracking markers were placed on the subject's own shoe to define the forefoot segment (medial and lateral quarters of the shoe, in the region of the base of the 1st and 5th metatarsals and the dorso-lateral aspect of the distal toe box). Two virtual markers were created using a digitising pointer (C-Motion Inc) at the most distal front edge of the shoe and the other at a point directly below the head of the 1st metatarsal head at the shoe/ground interface(1st met). All subjects walked at three different, self selected velocities: preferred, slow and fast. Three trials were collected at each velocity. A three factor (velocity and marker position with subject as a random factor) ANOVA was carried out to test for differences, this was followed up with post hoc paired t-tests.

RESULTS: The average toe clearance across all velocities were similar for the front edge of the shoe (mean 28.60mm, SD 9.30, median 27.35mm) and 1st met (mean 25.95mm, SD 9.10, median 26.60mm) (Figure 1). There was a significant effect of velocity on these results (p=0.02). At preferred and fast velocities the markers were within 2mm of each other however at the slow velocity there was a mean difference of 5.6mm, the 1st met being closer to the ground for all subjects.

CONCLUSIONS: The values for MFC are consistent with other studies. The difference in height between the 1st met and front edge of shoe is likely to have been caused by extension of the proximal metatarsalphalangeal joints. Further investigations of this mechanism may provide valuable information for muscle training programmes. The greater difference in MFC at the slow velocity is an interesting finding and may be relevant to populations that walk slowly e.g. older adults. It is worth considering however that the difference in clearance may not be velocity linked but rather a change in muscle activation pattern caused by a change due to the methodology adopted i.e. asking subjects to vary from their preferred velocity. Consequently, it would be valuable to repeat this study in populations with a known risk of falling and include electromyography.

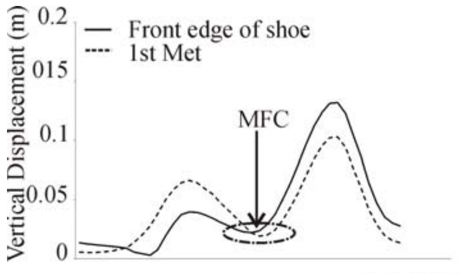

Figure 1

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Development of a posturography protocol for best identifying older fallers

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INTRODUCTION: Falls are a serious problem for older adults, associated with physical, psychological, and economical consequences [1]. Balance impairment is one of the leading causes of falls [1]. Posturography has the potential to identify individuals at high risk of falls, but its usefulness is limited by a lack of standardization in testing methodology and reporting [2]. The objective of this study was to develop a clinical protocol that allowed for the best differentiation of fallers and non-fallers using posturography. The developed protocol recommends the testing condition to use and the postural sway parameters to calculate to achieve this, while also providing an equation to calculate fall-risk.

METHODS: 150 adults aged 65 – 97 participated. Subjects were classified as fallers if they reported at least two falls in the past year. Subjects performed four 60-second quiet-standing balance tests in a randomized order: Eyes Open, Comfortable Stance; Eyes Closed, Comfortable Stance; Eyes Open, Narrow Stance; and Eyes Closed, Narrow Stance. Center of pressure data was collected at 1000 Hz using a Bertec balance platform. Eight traditional sway parameters were calculated. Detrended

Fluctuation Analysis was used to calculate fractal measures. Stepwise logistic binary regression was performed for each testing condition determined the best group of postural sway parameters to differentiate individuals based on fall status. Somers' D values were calculated for each model to indicate model fit, with a value of 1 indicating the best fit.

RESULTS: Table 1 lists the parameters included in the logistic regression model for each condition. Somers' D values are also given. Eyes Closed, Comfortable Stance is recommended for use based on the high Somers' D value. The associated logistic regression model is: Logit (p) = -20.6730 + 0.0775 * Age + 0.1355 * BMI – 3.9006 * Mean Frequency + 0.2044 * M/L Velocity – 12.8356 * M/L Short Term α-scaling Exponent + 16.9492 * A/P Short Term α-scaling Exponent

CONCLUSIONS: This study is a step toward making posturography a more viable clinical tool for quickly screening older patients' fall risk. The developed protocol demonstrates the need to incorporate more than a single postural sway parameter, while also showing the importance of both traditional and fractal measures. It identified medial-lateral sway velocity as the parameter that best differentiated subjects based on fall history.

ACKNOWLEDGEMENTS: We wish to thank Thomas Adams II, Haluk Ay, and Zhen Wang.

	Eyes Closed Comfortable Stance	**Eyes Open Narrow Stance**	**Eyes Closed Narrow Stance**
M/L Velocity	M/L Velocity	M/L Velocity	M/L Velocity
Mean Frequency	A/P Short-Term α-scaling exponent		M/L Sway Range
	M/L Short-Term α-scaling exponent		A/P Short-Term α-scaling exponent
	Mean Frequency		
	BMI		
	Age		
0.438	0.715	0.417	0.558

Table 1 Logistic regression findings by condition

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Voluntary step execution test to identify and predict falls and injury severity in old adults

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INTRODUCTION: Stepping reactions play a critical role in responding to balance perturbations whether they are a consequence of external perturbation or self-induced in nature [1]. The present study aimed to 1) retrospectively and 2) prospectively determine the capacity of voluntary stepping performance under single and dual task conditions to identify and predict (respectively) future falls among older community-dwelling persons. 3) Also this study aimed to explore whether Voluntary Step Execution Test can predict the severity from fall.

METHODS: Voluntary Step Execution Test performed as a reaction time task while standing on a force platform under single task and dual task conditions. Step initiation phase, foot-off and -contact time, preparatory and swing phases were extracted from center of pressure and ground reaction force data were tested to identify older adults who live independently in the community. Than One-year fall incidences were monitored on the same 100 old adults (mean age = 78.4±5.7).

RESULTS: The retrospective results show that there were no statistically significant differences between non-fallers and fallers across all step execution parameters under the single task condition. However, adding cognitive load to the Voluntary Step Execution Test revealed statistically significant increases in duration of the preparatory phase, swing time and the time to foot-contact (p= 0.035; p= 0.033 and p= 0.037, respectively). Based on the coefficients of the logistic regression model participants with dual task step execution times ≥1100ms had 5 times the risk of falling than participants with execution times <1100 ms. Ninety-eight subjects completed the one-year follow-up, 49 nonfallers, 32 one-time fallers and 17 recurrent fallers (two or more). Recurrent fallers have significantly slower voluntary step reaction times in both single and dual task conditions due to slower preparation and swing phases. Thirteen fallers who needed medical attention as a result of a fall had significantly slower voluntary step reaction times during dual task condition compared with non-injured fallers as a result of slow step initiation phase. Stepwise (backward) logistic regression analysis showed that elderly persons with slower step reaction times during dual task condition had 5.65 times the risk of falling than nonfallers and 4.56–7.83 times the risk of needing medical attention than non-injured fallers.

CONCLUSIONS: Voluntary Step Execution Test is a simple and safe examination that has the ability to effectively identify and also predict future falls using its cognitive paradigm, higher odds ratios were found for the dual compared to the single task [2]. To our knowledge, this study is the first to demonstrate prospectively differences in voluntary stepping response in dual task condition between older adults who subsequently were or were not injured as a result of a fall [3].

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Medio-lateral stability of sit-to-walk performance in older individuals with and without fear of falling

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INTRODUCTION: Most falls in older people occur due to loss of balance during everyday locomotion, e.g. when initiating gait from sitting; sit to walk (STW). The aging effects on balance appear most critical in the medio-lateral (ML) direction [1]. It has been argued that the broader stride width in gait, seen in many people with fear of falling (FoF), does not necessarily increase stability, but could be predictive of future falls, maybe due to increased ML velocity of the body centre of mass (CoM) [2]. This is, to our knowledge, the first study aimed at examining step-, velocity- and stability-related parameters focusing on ML stability, in the STW performance of people with and without FoF.

METHODS: Ten subjects with FoF and 10 matched controls, aged ≥70 years, with the ability to rise up and walk independently ≥10 m were included. Synchronous kinematic and kinetic data collection was carried out in a laboratory. At least 5 STW-trials at self-selected speed were analysed per person. For the kinematics 38 reflecting markers were used for construction of a model of 13 segments from which the CoM was calculated. Force plate data were used for identification of the events: seat off and first and second toe off. Stability parameters were calculated according to a formula implying that the vertical projection of the CoM extrapolated by adding its velocity times a factor $\sqrt{l/g}$ (height of inverted pendulum divided by gravity) should fall within the base of support (BoS) [3]. A related spatial margin of stability (SMoS), defined as the minimum distance from the extrapolated CoM (XcoM) to the boundaries of the BoS was also calculated. Pairwise comparisons, including variability, were made by the use of nonparametric statistics.

RESULTS: In the sequence 'seat off–second toe off', the FoF group showed significantly ($p<0.05$) shorter and broader steps, lower forward but similar ML CoM velocity, broader CoM and XcoM widths, no SMoS differences (Fig. 1), though higher intra-individual variability of XcoM width.

CONCLUSIONS: Older people with FoF show signs of poor stability – comparable to results from previous gait studies – during the STW performance, which may indicate an increased risk of falls and fractures.

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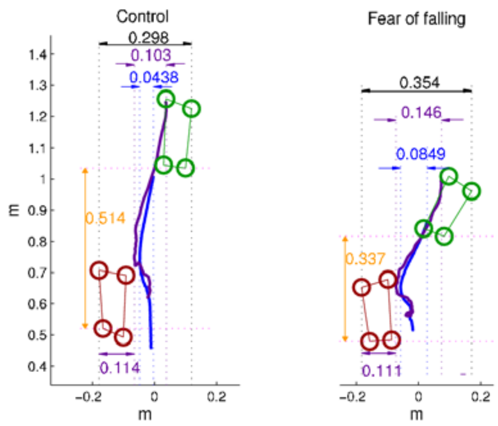

Fig.1 Step and stability parameters of typical STW-trials of one matched subject pair. The circles define the maximal support area during single stance 1 and 2. Variables indicated (from above): widths of step, XcoM and CoM, step length and minimum SMoS (m). The thick lines indicate CoM and XcoM trajectories

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User Evaluation of Multifaceted Activity Monitoring System for Fall Prevention

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INTRODUCTION: In the last decade, both methodological strategies and technological interventions were defined to prevent falls [1]. Unfortunately, all the measures were found to be too restrictive (from a patient's mobility point of view), and limited in terms of efficacy [2]. All the current systems are targeted either on the service provider side (i.e. assessment tools, incident reporting) or on the client side (i.e. technological aids for individuals). Conversely, Fallarm realizes a multifaceted strategy (as discussed by [3]) based on closed-loop information exchange between proactive and reactive methods: comprehensive assessment protocols determine the individuals' risk of falling; an innovative device continuously monitors subjects' activities and it provides patients with constant feedback about their actual risk to increase their awareness; simultaneously, it aims at preventing adverse events, and it reports any incident. Thus, Fallarm is a comprehensive solution for the remote management of a person's risk of falling 24 hours a day. For the purpose of this study, we evaluated the usability of our solution in two contexts: hospital (the European Institute of Oncology - IEO) and home settings. We compared the wrist and the waist as the preferred position for the fall detector.

METHODS: We developed eight prototypes of the device. 20 subjects (6 males and 14 females, aged from 25 to 88) were recruited to perform the test. All of them had normal sensitivity, and they were physically able to walk. Subjects were equipped with two devices: one on the right hip, and the other on the left wrist. They were required to autonomously put the equipment on, and to wear it for 10 hours while carrying out their daily activities. During the experiment the prototypes raised an alarm at random, simulating an increase of the level of risk. Both the devices monitored the inertial parameters of the subjects for the duration of the whole tests. At the end of the experiment, subjects filled an evaluation questionnaire to indicate their preference.

RESULTS: Our solution was accepted by the majority of subjects (95%). They would straightforwardly use the device on the wrist; otherwise, they would not utilize it at all (or they would accept it only if they are ought to). All subjects were able to easily put on themselves both the devices, and they were able to perform all the activities they ordinarily carry out. In terms of psychological impact, the difference between the two locations is noteworthy ($p = 0.02$).

CONCLUSIONS: Results confirmed the applicability of the fall detector mounted on the wrist, which is the most comfortable position for the subjects, and the best placement for an activity monitoring device. Moreover the introduction of an interactive device encouraged subjects' mobility because the Risk Awareness Provider helps them to feel safer. Furthermore, the integration between proactive and reactive methods supports the documentation of adverse events (which is still a methodological pitfall in hospitals) and the reuse of previously acquired knowledge.

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Changes in Balance, Functional Performance and Fall risk after Whole Body Vibration Training and Vitamin D supplementation in Institutionalized Elderly Women, A 6 month Randomized Controlled Trial

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INTRODUCTION: Falls are one of the most leading causes of disability, injury and death among older adults, and thus constitute an important public health issue [1]. Fortunately, some of the risk factors for falls can be improved with intervention training, such as the age related decreased postural control and muscle strength [2]. Although the trainability of muscles in older people is well established, exercise interventions may not be too vigorous for the very old age group because of the higher risk for injury and low compliance. Whole Body Vibration (WBV) training has aroused interest as an efficient alternative for conventional resistance training in older adults (<80 years) by showing remarkable increases in muscle strength after long-term WBV [3, 4]. In healthy community-dwelling elderly there is evidence that long-term WBV training has a positive effect on several aspects of postural control [3, 5]. Conclusive evidence on the neuromuscular effects of vibration training in institutionalized elderly above 70 years of age, however, is scarce. Besides exercise interventions, vitamin D (and calcium) supplementation has aroused interest as an efficient strategy to influence neuromuscular performance and fall risk in elderly [6]. The optimal dose of supplementation however, is not known yet. Therefore, this randomized controlled trial investigated the effects of 6 months Whole Body Vibration (WBV) training and/or vitamin D and calcium supplementation on balance, functional performance and fall risk in institutionalized women above 70 years of age.

METHODS: 111 subjects were randomly assigned to four groups (2 WBV or 2 Control groups) who received a Conventional Dose (CD, 880IU) or a High Dose (HD, 1600IU) of vitamin D: WBV CD (n=28), WBV HD (n=26), CON CD (n=28) and CON HD (n=29). All subjects also received daily calcium supplementation (1000mg). The WBV group performed three times weekly static and dynamic exercises on a vibration platform. The CON group did not receive any exercise intervention. Balance was evaluated by computerized posturography; Functional Performance was analysed by the walk across (determining step length and step width), the Time to Get up and Go test (TUG), the 10m walk test and the Shuttle Walk (investigating endurance capacity); Fall risk was measured by the Physiological Profile Assessment.

RESULTS: For none of the measured parameters, a high dose of vitamin D resulted in a better performance than a conventional dose. The improvements in the WBV group in endurance capacity (+9,5%), time to walk 10m at preferred speed (-10%), time to perform the TUG at preferred (-13,2%) and maximal (-7,8%) speed were significantly larger than the changes in the CON group (-1,1%, -5%, -3,2 and -5,2 respectively). No surplus value of WBV training upon vitamin D and calcium supplementation could be detected in fall risk and postural control parameters.

CONCLUSIONS: A high dose of vitamin D supplementation (1600 IU) was not more efficient than a conventional dose (880IU) in improving postural control, functionality and fall risk in institutionalized older women. This trial showed a surplus value of WBV training upon vitamin D and calcium supplementation in the enhancement of walking, Time to Get Up and Go performance and endurance capacity. This benefit could contribute to an improved quality of life.

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Eye and body movement strategies during turning tasks in older adults at risk of falls

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INTRODUCTION: Falls and recurrent injuries have been attributed to turning as we carry out daily activities, with the risk of falling increasing as we age. Although there is limited knowledge about how turning is controlled, studies of healthy adults have indicated a clear order of eye, head, trunk and foot movements during a visually cued step turn. However, this hierarchical order of movement is unclear for older adults at risk of falling. Also, a temporal order of anticipatory muscle activity and the preparatory role of centre of pressure are yet to be established in this population. The general hypothesis of the current study is that there is a temporal order to visually cued eye, head and body orientations in a population of older adults at risk of falling. Specifically, it is expected that the spatial and temporal onset of movement will be similar to that of the healthy adult. However, an increased latency to eye movement and onset of anticipatory postural adjustments (APAs) will be observed in this at risk population. This study aimed to identify a temporal relationship of preparatory movement, muscle activity and centre of pressure in older adults at risk of falling. It also aimed to clarify these relationships in healthy older adults.

METHODS: 22 participants (aged 65- 85 years) were allocated to a “falls risk” (n=11) or “healthy” older adult (n=11) group based on their scores on a falls risk assessment tool. Participants performed visually guided step turns to locations at 30 or 60 degrees to the left and right of their starting position. Electro-oculography (EOG) was used to measure onset of eye movement, an AMTI forceplate collected centre of pressure (COP) data, a Qualysis motion analysis system collected 3-D movement data, and a Bortex telemetered system collected electromyographic (EMG) data of lower limb muscle activity. Ten turns towards each peripheral location were completed in a random order (total of 40 trials collected).

RESULTS: Preliminary data indicated a temporal segmental order of eye, head and foot movement in both healthy older adult and falls risk older adult, with the eyes and head moving at about the same time. Secondly, both the healthy and falls risk older adult employ a similar step strategy and movement of COP, with COP movement consistently presenting as the first anticipatory postural adjustment (APA). Thirdly, the onset of COP, head and eye movement is earlier in the falls risk older adult. Fourthly, preparatory muscle activity in the healthy older adult initiated almost simultaneously in both limbs- distally to proximally. However, in the falls risk older adults, muscle activity appears to initiated in one limb, prior to the onset of activity in the other limb.

CONCLUSIONS: The earlier onset of anticipatory COP, head and eye movement in the falls risk older adult may indicate a preparatory strategy to enable a stable visual platform to assist turning tasks. Findings also indicate that the onset of muscle activity may differ in older adults at risk of falls with muscle activity isolated to one limb in order to maintain perceived stability when changing direction. COP may be a more consistent indicator of anticipatory postural adjustments onset compared to muscle activity or observed movement. Further data collection and analysis is required to verify these findings.

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The influence of fear and physiological risk of falls on gait in older people

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INTRODUCTION: Previous studies have indicated that gait patterns in older people may be affected by concern about falling [1,2]. The aim of this study was to examine the effects of concern about falling and physiological falls risk on gait performance using a paradigm in which concern about falling was experimentally induced.

METHODS: Forty-four community-living older adults (17 males, 27 females) with a mean age of 76.8 (SD=5.2) years walked at self-selected speeds on the floor and a 60cm elevated walkway in normal and dim lighting conditions. Temporal and spatial gait parameters, muscle activity, measures of physiological arousal, physiological falls risk, and concern about falls were assessed.

RESULTS: Physiological falls risk was associated with slower walking speeds in all conditions including the optimal (floor) condition (p=0.029). In the elevated walkway conditions, concern about falls (both self report and as indicated by physiological arousal) was increased and participants walked more slowly, took shorter steps, decreased their cadence and spent more time in double support (p<0.005). Disproportionately large reductions in walking speed were evident in participants with greater concern about falling (p=0.018), as shown in Figure 1.

CONCLUSIONS: These findings suggest that walking performance is influenced by both physiological and psychological factors. Physiological falls risk appears to determine walking speed under optimal conditions, whereas concern about falling elicits greater (possibly excessive) gait adjustments under conditions of postural threat.

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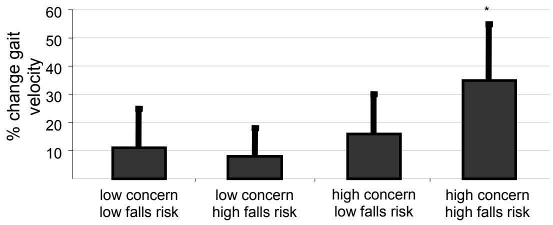

Fig.1 Mean (±SEM) percent change in gait velocity between floor and elevated conditions, across subgroups of older adults categorised with high/low concern regarding falls and high/low physiological risk of falls.

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Identifying the causes of falls through wearable sensors

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INTRODUCTION: Falls are the number one cause of injury in older adults. Efforts to prevent falls are challenging, due in part to a lack of direct evidence on the circumstances surrounding falls in real life. Wearable sensor arrays (e.g. accelerometers) represent a promising technique for providing insight on the cause of falls. Previous studies have shown that the occurrence of a fall can be sensed reliably based on the high acceleration at impact [1, 2]. Our goal is to develop a wearable sensor array also capable of documenting the cause of the fall (e.g., slip, trip, faint). As an essential first step in this process, this study examined how the location and number of acceleration sensors influence the accuracy of the system in differentiating three separate types of falls acquired in the laboratory (slip, trip, other collapse).

METHODS: Ten subjects (aged 20-35) participated in trials involving falls due to slips, trips, and "other" causes. In slipping trials, participants walked over low-friction plastic sheets and either acted out a slip (n=3) or were made to slip by quickly translating the surface (n=3). Trips were simulated with a tether attached to the subject's ankle (n=3), or by acting out stumbling over an obstacle (n=3). "Other" falls were simulated by having the participant act out fainting (n=3), or loss of balance following reaching (n=3), turning (n=3), sitting down (n=3), and rising (n=3). 3D position data were collected at 120 Hz from markers at the head, sternum, waist, and feet, and differentiated to estimate accelerations. The means and variances of the X, Y and Z accelerations of each marker for the 1000 ms prior to pelvis impact were input to a linear discriminant model for fall type classification. Analysis to date has focused on data from 3 subjects, with the data split evenly between model training and evaluation.

RESULTS: The sensitivity of the classification algorithm depended strongly on the on the location and number of markers, and varied considerably between different types of falls. With a single marker, the best sensitivity was provided by the head marker, which was at least 63% sensitive (Table 1). With two markers, the sternum and head combination was most effective, with at least 87% sensitivity. For three markers, the best sensitivity (at least 83%), provided by the combination of right foot, left foot, and sternum, was no better than the two-marker sternum and head combination.

Table 1 Sensitivity of marker arrays in detecting the cause of falls

Marker combination	Sensitivity (percent)		
	Slips (n = 21)	Trips (n = 23)	Other (n = 19)
Head	71	83	63
Sternum	86	56	79
Waist	57	78	74
Left Foot + Right Foot	81	78	100
Waist + Sternum	62	74	74
Waist + Head	90	87	63
Sternum + Head	90	87	95
Left Foot + Right Foot + Waist	81	87	95
Left Foot + Right Foot + Sternum	86	83	100
Left Foot + Right Foot + Head	76	87	84
Waist + Sternum + Head	71	83	95

Table 1

CONCLUSIONS: 3D acceleration data from as few as two wearable markers, input into a linear discriminant model, provided at least 87% accuracy in separating slips, trips, and other types of falls.

ACKNOWLEDGEMENTS: Supported by NSERC RGPIN239735.

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Effect of a new fall prevention program designed for persons with osteoporosis

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INTRODUCTION: Fractures of wrist and hip are a frequent consequence of falls in the elderly. People with osteoporosis are particularly at risk for fall related fractures, because of decreased bone strength. It has been shown that exercise programs can prevent falls and fall-related injuries in the elderly. [1] The 'Nijmegen Falls Prevention Program' ('NFPP') has shown to be successful with a 46% reduction of the number of falls in community-dwelling elderly. [2] This program consists of gait, balance and co-ordination training on an obstacle course, walking exercises in a crowded environment and the training of fall techniques derived from martial arts. However, patients with osteoporosis were excluded from this program, because of safety reasons. The benefits of a falls prevention program for patients with osteoporosis, however, are expected to be large. Therefore, the NFPP was adjusted for patients with osteoporosis and the adjusted program was evaluated for its efficacy in a randomized clinical trial. Recently, it has been argued that falls prevention programs may not be beneficial in terms of quality of life, because the reduction in the number of falls may be due to participants gaining more fear of falling and becoming less active.[3] Therefore, the efficacy of the NFPP for persons with osteoporosis was not only evaluated with respect to fall frequency, but also with respect to fear of falling, activity level and quality of life (QoL).

METHODS: A total of 92 community-dwelling elderly persons with osteoporosis (mean age (SD): 71.0 (4.7), 86 female, 6 male; T-score ≤ -2.5), were included in this study. After a baseline measurement (M1), participants were randomly allocated to an exercise group (n=47) and a control group (n=45). Subsequently, the exercise group participated in the NFPP for persons with osteoporosis for 5.5 weeks whereas the control group received usual care. After the program had ended the second measurement took place (M2) followed by the third (M3) after one year follow-up. Primary outcome measure was fall incidence, measured for one year by means of monthly fall registration cards. Furthermore, at M1, M2 and M3, balance confidence was measured with the Activity-Specific Balance Confidence (ABC) scale and QoL with the Quality of Life questionnaire of the European foundation for osteoporosis 41 (Qualeffo-41). Activity level was assessed with a pedometer for seven consecutive days. The mean number of steps a day was included in the analysis. In addition, laboratory assessments of obstacle avoidance while walking on a treadmill were performed. The outcome measures were analysed by means of a repeated measures ANOVA, with 'Measurement' as within and 'Group' as between subject variable.

RESULTS: Preliminary results show a reduction of 36% in fall incidence rates in the exercise group (0.75 falls/year) compared to the control group (1.17 falls/year). Balance confidence increased in the exercise group after participation to the program, albeit not significantly (mean (SD): 57(21)% to 64(19)%). Balance confidence, QoL and activity levels remained the same in both groups for all three measurement moments. There were no significant differences in obstacle avoidance performance between the exercise and control group as well.

CONCLUSIONS: The efficacy of a new falls prevention program specifically designed for persons with osteoporosis was tested in an RCT. Preliminary results showed that the program was effective in reducing the number of fall incidents. This was not due to a decrease in activity levels caused by increased fear of falling. Quality of life also remained at the same level. Final results will be available mid 2009.

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Kinetic study of gait termination

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INTRODUCTION: Gait termination is the transition from rhythmical, repetitive gait to a complete stop. As gait initiation has been well studied, the gait termination mechanisms have received less attention. The purpose of this study is to describe kinetic characteristics as the trajectory of the centre of pressures (COP) and breaking forces during gait termination.

METHODS: Fifteen adults were included. Planed stopping was realised at two walking speeds ('natural' and 'fast' speed). We recorded kinematic parameters by means of video motion analysis (6 infrared cameras). A force platform recorded kinetic parameters (ground reaction forces) and the trajectory of the COP.

RESULTS: Gait termination can be defined in 3 phases (Fig.1). During the first phase, we record a sagittal displacement of the COP (correlated with the walking speed). During the second phase, we observe a backward and lateral displacement of the COP. The lateral displacement of the COP is consecutive to a lateral movement of the whole body. We observe a correlation between the backward displacement of the COP and the breaking forces during stop. After the two feet are immobilised to the ground, compensatory postural adjustments occur (3rd phase). These compensatory postural adjustments follow the 2 first phases of the trajectory of the COP. The correlation is positive between gait parameters and the trajectory of the COP during the 3rd phase.

CONCLUSIONS: The three phases of gait termination have different objectives: Phase 1 is a breaking sagittal phase of the whole body. Phase 2 corresponds to early adjustments corresponding to backward and lateral displacement of the COP (backward displacement related to gait parameters and breaking forces). Phase 3 consists in compensatory postural adjustments related to gait parameters. There are many applications of this study, especially in elucidating mechanisms of falls. The inability to terminate activities such as walking has been reported as a predisposing factor for falls. A better definition of kinetic parameters during gait termination will allow us to determinate which kinetic parameters could be considered as fall risk factors.

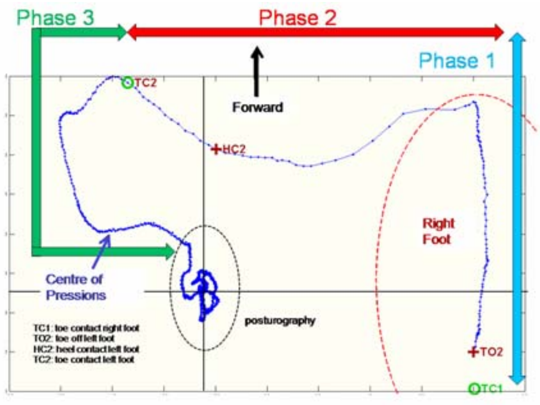

Fig.1 The three phases of COP trajectory during gait termination.

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The predictive value of postural balance measurements for falls in the elderly

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INTRODUCTION: To predict future falls with help of a forceplate remains difficult caused by a lack of prospective studies. Therefore, more prospective fall assessment studies are needed that use posturography. The aim of this study was to determine whether postural balance variables measured with a forceplate were able to predict risk for multiple falls in a community-dwelling elderly population.

METHODS: Two hundred seventy independently living elderly persons (73 ± 7 years) participated in both a single and a dual cognitive task test. Task performance was performed with and without vision. Balance variables assessed were maximum displacement and root mean square amplitude in the medial-lateral (Max-ML, RMS-ML) and anteroposterior direction (Max-AP, RMSAP), mean displacement in the medial-lateral direction (Mean-ML), average speed of displacement (V), and the area of the 95th percentile ellipse per given time (AoE). Falls were prospectively recorded during 1 year with a fall calendar.

RESULTS: Eighty-five (31%) multiple fallers with a total of 384 falls and 185 (68%) non- or one-time fallers (53 falls) were recorded. Logistic regression was used to identify the variables predicting multiple fallers. RMS-ML in the single-task condition (odds ratio, 21.8) continued in the model together with the covariables history of multiple falls (odds ratio, 5.6), use of drugs (fall risk medications or multiple medicine use; odds ratio, 2.3), and gender (odds ratio, 0.34). Self-chosen stance width showed a difference between multiple fallers and nonmultiple fallers.

CONCLUSIONS: The postural balance variable RMS-ML predicts future fall risk in women with a history of multiple falls who take fall-risk medications or use multiple medicines. Multiple fallers were shown to position themselves with a narrower stance during balance.

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Characterizing evoked autonomic activity in compensatory balance control

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INTRODUCTION: Perturbations to stability represent an ecologically valid threat to safety that must be attended to in a timely and appropriate manner to avoid a fall and associated injury. Accordingly, transient instability may be regarded as an 'emergency' situation, and this series of studies examined how the sympathetic division of the autonomic nervous system, classically linked to fight or flight reactions, was activated during compensatory postural reactions.

METHODS: Transient external perturbations using both standing (lower limb) and seated (upper limb) paradigms evoked compensatory postural reactions, verified by electromyography and force plate measurements, in young, healthy participants. Autonomic reactions were assessed using measures of electrodermal activity at the palmar surface, which is unique in that sweat glands in this region respond primarily to emotive stimuli and have a minimal role in thermoregulatory sweating.

RESULTS: Perturbation-evoked electrodermal responses (EDRs) were observed in over 90% of trials, with a mean onset latency of 1962 (SD 151) ms post-perturbation. Similar to compensatory postural reactions, the amplitude of perturbation-evoked EDRs attenuated over the first few trials, but unlike EDRs evoked by other non-perturbation stimuli, they did not completely habituate (even after as many as 60 trial repetitions) [1]. The amplitude of perturbation-evoked EDRs demonstrated sensitivity to stimulation characteristics and was scaled to perturbation amplitude. In addition, perturbation-evoked EDRs were modulated by manipulations that influenced execution of the compensatory reaction, including predictability of the evoked instability and challenge of the evoked response. Initial baseline levels of arousal were found not to influence the amplitude of perturbation-evoked EDRs. It was determined that perturbation-evoked EDRs are uniquely sensitive to the context of instability, as EDRs evoked during compensatory postural reactions were larger and more consistent than potentials evoked by purely motor or sensory stimuli which comprise a compensatory reaction [2].

CONCLUSIONS: These findings suggest that autonomic contributions likely play some role in compensatory behavior, although the specific nature of this relationship is not clear. Ongoing work is focused on more precisely identifying the how sympathetic drive may contribute to appropriate compensatory behavior and how autonomic dysfunction in certain older adults and clinical populations (such as Alzheimers' Disease) may be related to balance impairment and increased fall risk.

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"That's ok, I'm strong, I won't fall" - Is strength a good predictor of postural stability during normal quiet stance?

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INTRODUCTION: Sensorimotor information is important for the maintenance and regulation of postural stability. This investigation specifically concerns itself with body mass and force production capabilities and how they may interact to impact postural regulation. Several recent studies have investigated these characteristics and demonstrated that body weight is a strong predictor (approximately 50% of the variance) of postural stability (normal bipedal quiet stance) [1] and that a decrease in body weight (through diet and surgical intervention) improves postural stability [2]. A potential negative effect of a substantial body weight loss is a decrease in absolute muscular force production; however, this is generally well tolerated in individuals as their relative force values (normalized to body weight) improved [3]. This increase in relative muscular force may benefit, or enable prediction of postural stability, as of now the precise nature of muscular force as a predictor for postural stability in normal quiet bipedal stance is unknown.

METHODS: Subjects (n=43) were split into three groups, control (n=16, BMI <25 $kg \cdot m^{-2}$), obese (n=17, 30 $kg \cdot m^{-2}$ <BMI< 40 $kg \cdot m^{-2}$) and morbid (n=10, BMI >40 $kg \cdot m^{-2}$). All groups underwent both an initial (*pre*) and final (*post*) evaluation to determine baseline and final anthropometric, postural stability (centre of pressure speed, *cpspeed*) and force values (leg extension) measurement. Obese subjects underwent a diet intervention program as a weight loss strategy and were tracked until resistance to weight loss occurred (*post* measure). Morbid subjects underwent bariatric surgery (duodenal switch procedure) and were tested at both three and twelve months, post-surgery (*post*). All postural stability parameters were measured in *vision* and *no vision* conditions; results are reported for *no vision* conditions.

RESULTS: Regression analyses indicate that the muscular force ratio (*force max·weight*$^{-1}$) for *pre* and *post* phases explain approximately 25% (r^2 = 0.25, p=0.001) and 1% (r^2 = 0.01, p=0.47) of the variance in *cpspeed*, respectively. Simple regression analyses on *force max* and *cpspeed* reveal no significant relationship for either *pre* or *post* phases, furthermore, a forward stepwise linear regression (variables included *weight*, *force max·weight*$^{-1}$, *force max* and *Body Mass Index*) indicates that weight is the strongest predictor (r^2 = .42) of postural stability.

CONCLUSIONS: These preliminary results indicate that force production capabilities (when normalized to body mass) are poor predictors of postural stability performance in normal quiet bipedal stance, especially in light that the relative improvements in force production capabilities occurred simply from weight loss and not through a training intervention (although we do not question the importance of strength training for frail individuals, we do question its usefulness in these conditions). We suggest two possible explanations for the increases in postural stability with weight loss, these are: i) a purely mechanical effect, the decreased inertia associated with a body mass reduction permits a greater postural regulation and ii) an increased body mass may overload the plantar surface mechanoreceptors thereby reducing the quality of the sensorimotor information available for postural regulation.

ACKNOWLEDGEMENTS: The authors would like to acknowledge NSERC's support.

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Indomethacin does not influence postural balance and manual reaction time in healthy middle-aged individuals

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INTRODUCTION: Accidental falls in the elderly are a major health and research topic. Increased reaction time and impaired postural balance have been determined as reliable predictors for those at risk of falling [1], and are important functions of the central nervous system (CNS). Another risk factor for falls is medication exposure. Amongst the medications related to accidental falls are the non-steroidal anti-inflammatory drugs (NSAIDs) [2]. About 1-10% of all users experience CNS side effects. These side effects, such as dizziness, headaches, drowsiness, mood alteration, and confusion, seem to be more common during treatment with indomethacin [3]. Considering this, it is possible that maintenance of (static) postural balance and swift reactions on stimuli are affected by exposure to NSAIDs, indomethacin in particular, thus putting elderly individuals at a greater risk for accidental falls. By means of a randomised controlled trial, the influence of highly dosed indomethacin in healthy middle-aged subjects on two important predictors of falls, postural balance and reaction time, was studied.

METHODS: Twenty healthy individuals (50-68yrs) participated in this double-blind, placebo-controlled, and randomised crossover study. Three measurements consisting of a set of postural balance tasks and manual reaction time tasks were conducted with a week interval each. For the first measurement indomethacin 75mg (slow-release) or a visually identical placebo was randomly assigned to the subjects. Prior to each measurement, a total of 5 capsules were taken in 2.5 days. The second measurement (baseline) was without intervention, the final one was again with intervention, only this time the placebo group from the first measurement got indomethacin and vice versa.

RESULTS: Repeated measures ANOVAs revealed no significant differences in quiet stance between the 3 experimental conditions (indomethacin, placebo, and baseline) in any of the parameters of all balance tasks. No differences in postural balance were found between the single and dual task conditions, and on the performance of the dual task itself. When vision was ruled out, there was significant more body sway than with eyes open, but this was similar for all experimental conditions. Similarly, no significant differences were found on the manual reaction time tasks between the experimental conditions.

CONCLUSIONS: Highly dosed indomethacin (150mg/day) did not influence any of the balance or reaction time tasks assessed in healthy middle-aged individuals. Putting these results into perspective with previous research studying the influence of medications or alcohol on postural balance and manual reaction time, the conclusion is that indomethacin does not affect these functions of the central nervous system. Consequently, there appears to be no reason to link this drug to an increased risk of falling as far as the involvement of postural balance, even combined with dual tasking, and reaction time is concerned.

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The effect of Methylphenidate on postural stability under single and dual task conditions in children with Attention Deficit Hyperactivity Disorder - A double blind randomized control trial

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INTRODUCTION: Attention deficit hyperactivity disorder (ADHD), is one of the most prevalent neuropsychiatric disorders in children. ADHD affects 3 to 5% of school age children. Given the known deficits in attention in ADHD, and the evidence suggesting that balance control during walking requires attention [1] and children with ADHD moved their head more times, moved a longer distance and covered a greater area during sitting [2]. It has been shown that hyperactive children on MPH managed to balance on a board that rotated about a central steel shaft for a longer time than placebo controls [3]. We sought to investigate the effects of MPH on postural stability during standing in ADHD children, in both single and dual task conditions. We tested the following hypotheses in order to gain insight into the effects of MPH on stability in ADHD: (1) After administering MPH, postural stability of ADHD children will improve; (2) The influence of MPH would be more prominent during a dual task condition. This hypothesis is based on recent results showing that MPH treatment significantly decreased stride time variability and enhanced the automaticity and consistency of gait in ADHD.

METHODS: A randomized controlled double-blind study analyzing postural stability in 24 ADHD children before and after MPH vs. placebo treatments, in three task conditions: (1) Single task, standing still; (2) Dual task, standing still performing a memory task; (3) Standing still listening to music**.**

RESULTS: MPH resulted in a significant improvement in postural stability during the dual task condition and while listening to music, with no equivalent improvement in placebo controls.

CONCLUSIONS: MPH improves postural stability in ADHD, especially when an additional task is performed. This is probably due to enhanced attention abilities, thus contributing to improved balance control during performance of tasks that require attention. MPH remains to be studied as a potential drug treatment to improve balance control and physical functioning in other clinical populations.

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Feed-forward control of walking velocity in a biologically inspired walking biped model

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INTRODUCTION: Human biped walking is the result of coordination of various neural centres that control particular aspects of the locomotor pattern. It has been proposed, and somewhat substantiated in animal work, that the basic timing and movement patterns in walking are produced by spinal circuits known as Central Pattern Generators (CPG). The goal of this work is to develop a basic CPG model that will generate muscle activation patterns for a basic musculoskeletal model and test the ability of this basic CPG model to control the walking velocity of the biped model. It is expected that modulation of the frequency of the CPG should correspond to changes in the walking speed of the biped, however the coordination of the movements of the model will be lacking due to the absence of feedback pathways in the model.

METHODS: A basic CPG was developed based on the work of Matsuoka [1]. This model produces reciprocal alternating output of two mutually inhibitory neurons with an adaptation effect. The frequency of oscillation of the can be controlled by altering the time constant for the adaptation effect [2]. A basic 5-segment (HAT, 2 thighs & 2 shanks) biped mechanical model was developed based on human anthropometrics. The biped model was actuated by 2 muscles acting at each hip joint, while the knee was passively controlled. Due to a lack of a balance controller in the model, the HAT segment was supported by a spring-damper. Forward dynamics was used to determine the kinematics of the model, with muscle activations determined by the CPG. The time constant of the adaptation term in the CPG model (τ_{ad}) was incrementally increased from 0.25s to 1.5s over a series of 1344 simulations and the walking speed of the model was assessed.

RESULTS: The model was able to reproduce a basic walking pattern (alternating stepping pattern, and forward waking velocity) for all simulations (See example in Figure 1). Most of the simulations carried out resulted in a walking pattern with a consistent velocity, although the stride length could vary considerably from stride to stride. The time constant of the adaptation term in CPG model was able to successfully modulate the average walking velocity of the biped model, although the relationship was substantially more variable than originally anticipated, particularly at high CPG frequencies (low values of τ_{ad}).

CONCLUSIONS: The speed of a biped walking model could be controlled by manipulating the frequency of a basic neural oscillator. However, the relationship between walking speed and CPG frequency remained variable in the absence of feedback mechanisms to deal with perturbations to the walking pattern that occur at ground contact. This work stresses the importance of modelling sensory feedback pathways in order to generate realistic walking patterns with biologically inspired walking models.

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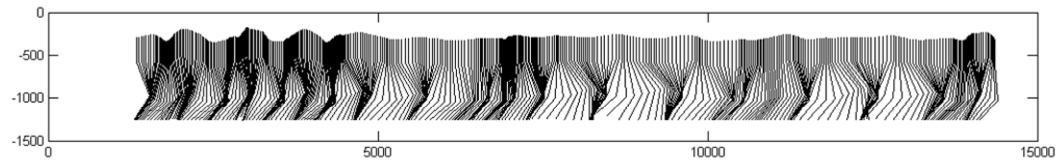

Walking Distance (mm)

Fig.1 Sample kinematics from a walking simulation

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Joint forces and torques during human walking in shallow water

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INTRODUCTION: The goal of this work was to estimate the internal joint forces and moments on the ankle, knee, and hip joints of young healthy adults during a complete cycle of walking in the terrestrial and aquatic (shallow water) environments.

METHODS: For that, we conducted an experiment in which 10 healthy young adults walked with self-selected comfortable speeds in both environments. In aquatic environment the individuals walked with water on the xiphoid level. In both conditions, we measured the components of ground reaction forces with a force plate and recorded the subject's movements with a video analysis system. To find the internal moments we used the inverse dynamics approach and the estimation of drag forces and moments were based on fluid mechanics [1].

RESULTS: During the trials, the subjects walked at lower speed in water than on land (0.50±0.04 m/s and 1.23±0.10 m/s, $p<0.001$), but their stride length was not different ($p=0.71$). In water, the vertical ground reaction force (GRF) magnitude was on average 1/3 of the GRF on land during walking. The angular displacement for hip, knee, and ankle joints presented similar patterns in both environments and the maximum angular amplitude was not different between water and land for any of these joints (p's>0.60).These results are in agreement with previous studies [2]. Concerning the kinetic variables, only a variable related to the ankle joint torque (normalized by body weight and lower limb length) was different between environments: the maximum plantar flexor torque during the support phase was 0.195±0.021 on land and 0.064±0.008 ($p<0.0001$) in water. The maximum knee flexor torque was 0.052±0.011 on land and 0.050±0.011 in water and the maximum knee extensor torque were, respectively, 0.047±0.047 and 0.028±0.004. For the hip joint, the results showed a maximum flexor torque of 0.064±0.018 on land and 0.061±0.012 in water and a maximum extensor torque of 0.085±0.021 on land and 0.084±0.017 in water. However hip and knee showed different torque patterns between environments (fig.1).

CONCLUSIONS: The results indicate that, in relation to walking on land, the subjects kept a similar joint kinematic coordination and the same spatio-temporal stride structure during walking in water at a comfortable speed even under the action of drag and buoyancy. For such, the subjects promoted changes in the patterns of internal joint moments in comparison to what they produced during walking on land.

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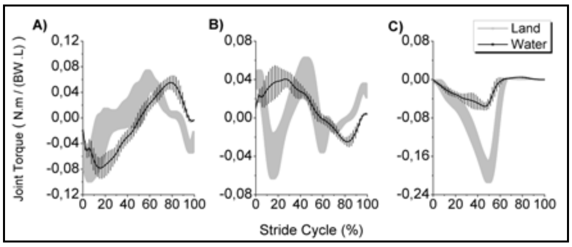

Fig.1 Joint torques for hip (A), knee (B) and ankle (C) during walking on land and water. Positive values indicate flexion for hip and knee and dorsi-flexion for ankle.

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Locomotor strategies associated with altered lower limb segmental mechanical properties

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INTRODUCTION: The human locomotor system possesses a profound ability to accommodate various changes to the musculoskeletal system. Previous work has revealed strategies used in response to changes in lower limb mass [1] or joint dysfunction [2]. Very little work has been devoted to revealing the changes in gait dynamics that occur due to limb length perturbations. The present study used stilt walking as a model to uncover these alterations.

METHODS: A motion analysis and force plate system was used to record 3D kinematic and ground reaction data from eight male subjects, walking with and without stilts (60 cm in height). For stilt trials, the segmental anthropometrics of the lower leg were redefined to include the human shank, foot and stilt. The stilt centre of mass position and principal moments of inertia had been empirically determined. Net moments and powers were calculated, then scaled non-dimensionally. Joint angles were normalized to the standing position. Paired-samples t-tests ($\alpha = 0.05$) were used to assess differences between peak joint angles in addition to points of interest on the net moment and power curves.

RESULTS: Peak knee flexion and hip extension were reduced in the stilt condition. With stilt use, the peak knee extensor moment at toe-off (KM3-S) and the peak hip and knee flexor moments (KM4-S and HM3-S) before heel-strike were increased with their associated powers (K3-S, K4-S and H3-S). The peak hip extensor moment at toe-off (HM2-S) and the peak knee abductor moment (KM2-F) were increased, while the peak hip abductor moment was reduced (HM2-F). Peak power generation at the hip during early stance (H1-S) and absorption during late stance (H2-S and H3-F) was reduced.

CONCLUSIONS: Increased shank length in the stilt condition was likely the cause of the increased magnitude of the eccentric knee extensor moment (KM3-S; K3-S). Interestingly, the peak knee flexion angle, occurring along with KM3-S and K3-S, was reduced in the stilt condition, which could be a means by which individuals attempt to attenuate abnormal knee loading. The reduced H2-S absorption with increased hip flexor moment was likely due to reduced hip extensor angular velocity, coupled with reduced relative walking speed. The H1-S generation in early stance was reduced in the stilt condition without differences in the HM1-S moment. Individuals exhibited a tendency to heel-strike with a more neutral hip position, which may offset the need for a large H1-S generation to prevent stance limb collapse and trunk control.

While the current study attempted to study the effects of acute changes in limb length on gait dynamics, it was not possible to separate those due to increased limb mass. This was evident by the increases in the knee flexor moment and power absorption (KM4-S; K4-S) at terminal swing and the hip ‘pull-off’ generation (H3-S) at toe off.

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A clinical significance of PID controller for keeping ability of lateral balance

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INTRODUCTION: Static postural stability is controlled by central nervous system, however it is unclear how nervous system controls muscles to produce corrective torque, which is an important issue in postural stability evaluation. Previous study has demonstrated that the static upright stance can be modeled as one-link inverted pendulum model using an optical postural sway measuring system [1]. By assuming that the postural corrective torque is regulated by a proportional-integral-derivative (PID) control, we investigated a clinical significance of parameters as the PID controller in lateral balance.

METHODS: Experiment 1; The subjects (50 dizzy patients with vestibular disorder and 50 age-matched healthy subjects) worn the white best attached a black circular marker of a 3 cm-diameter on the subject's back at the level of the fourth thoracic vertebrate and were asked to stand upright. For measurement of the movement of the marker, this system was composed of a CMOS video camera with a recording speed of 15 frames/s and a computer system for image recognition and data processing. Using body sway data for PID gain estimation, we identified the scalar parameters, Kp, K_D, K_I as PID controller. Experiment 2; In order to test the balance stability when proprioceptive inputs and visual inputs are unavailable in healthy subjects (n=5), they were also tested while they stood on a piece of foam rubber in comparison to on a rigid floor. The scalar parameters, Kp, K_D, K_I in each conditions were investigated.

RESULTS: Exp 1; The average value of K_D*I* which was calculated by K_D/mgh (m: body weight, g: the acceleration due to gravity, h: body height) in dizzy patients with vestibular disorder (0.0052±0.0014) was significantly lower than that in age-matched control subjects (0.0061±0.0015) during upright stance with eyes open ($p < 0.01$). While, there was no significant difference in the average value of K_P*I* (K_P/mgh) and K_I*I* (K_I/mgh) between the dizzy patients group and the control group ($p > 0.05$). Exp 2; The average values of K_D*I* in condition using foam rubber (0.013±0.002) were significantly higher than that on a rigid floor (0.008±0.003, $p < 0.01$) in upright stance with eyes closed.

CONCLUSIONS: These results suggest that the value of K_D*I* is associated with a balance-keeping ability and that the K_D*I* for detecting the balance disability in dizzy patients with vestibular disorder is clinically significant.

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In-vivo estimation of the forces at the cruciate ligaments during step up/down motor task

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INTRODUCTION: Knowing how knee anatomical sub-structures work in physiological conditions is fundamental for the development of new clinical, surgical, and rehabilitative procedures. The only possible way to reach this knowledge, without invasive measurements, is the modelling approach. The aim of this study was the estimation of the stabilization forces at the cruciate ligaments during the execution of a daily living motor task. The proposed model, integrated in a Gait Analysis System, would allow to estimate ACL and PCL forces during the performed movements.

METHODS: Subject-specific geometries and kinematic data were the foundations of the 3D quasi-static model adopted [1]. Each cruciate ligament was modelled using 25 elastic-linear elements, taking the fibre bundles and the anatomical twist of the fibres into account [2]. Subject-specific geometrical parameters were defined from data acquired using imaging technologies, such as nuclear magnetic resonance and 3D video-fluoroscopy. The elastic modulus values were taken from the literature for each fibre bundle. Finally, 3D vector force and the three anatomical components of the cruciate forces were estimated during 9 repetitions of the step up/down motor task.

RESULTS: PCL showed a negligible 3D force from full extension to about 20° of flexion. Then, PCL force increased until reaching the maximum value at full flexion, about 75° of flexion. Along the anatomical axes of tibia, PCL projected predominantly along the antero/posterior and proximo/distal directions. Behaviours obtained during extension and flexion movements were qualitatively similar, but force was greater during extensions. Variability between extension and flexion movements was similar, but as during extensions median curve was closer to the minimum curve, during flexions it was closer to the maximum one. ACL was inactive both during extension and flexion phase.

CONCLUSIONS: The inactivity of the ACL was due to the motor task considered, which tends to slack ACL and to stretch PCL [3]. Higher forces during extensions were probably due to the major activity of the muscles and to the inertial component to be won in order to perform the movement against the gravity force. On the other hand, the eccentric contraction of the muscles during flexion movements was needed just to control the movement in according to the gravity and so a minor stabilization was required by PCL. This was also corroborated by the fact that the median curve was closer to the minimum curve during extensions and closer to the maximum one during flexions. In conclusion the devised model was effective in evaluating forces at the cruciate ligaments during the execution of daily living activities.

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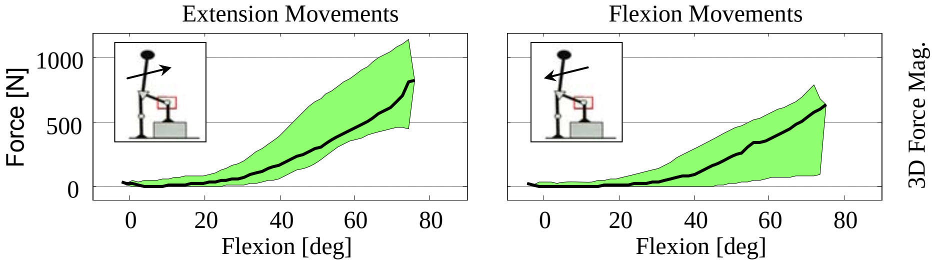

Fig.1 3D force magnitude of PCL during step up (left) and step down (right) phases, median curve inside the envelope produced by minimum and maximum curves

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Biomechanical analysis of dual mechanisms of 2 dimensional posture sway and learning.

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Introduction: The identification of learning curves for different motor tasks in changed force environments is a popular method of studying motor control. In the case of human postural sway, the pattern of the center of foot pressure (CoP) trajectory can be resolved into superposition of two components - the pressure distribution (PD) under the feet and loading-unloading (LU) of the legs [1]. We investigated the possible interplay and the relative contributions of PD and LU to the learning curve of a postural task in a novel force environment.

Methods: Subjects were asked to perform small amplitude, voluntary anterior-posterior (AP) sway of their center of mass (CoM) about their ankles in a rotating room. In a stationary room, AP sway involves active control of medio-lateral (ML) torques about the ankles directly related to AP PD under each foot. In a rotating room, a perturbing force acts orthogonal to CoM velocity, and subjects may rely on the PD mode of generating AP torques and/or the complementary LU mode of controlling the lateral CoP trajectory in order to return to baseline AP sway. We attempt to model the bio-mechanics of our system and to simulate the experimentally observed behavior of the CoM and CoP trajectories [2]. The model features: 1) 2-leggedness which passively contributes to the stability of the system via simple bio-mechanics; 2) the possibility of the lateral loading-unloading of the legs as tracked by the relative weight partition fraction between the legs; 3) a novel feature of possible pivot shifts between the two legs contingent on the interplay of a) asymmetric load distribution and the medio-lateral sway component of CoM and b) the choice of the engaged leg that can actively contribute to the changes in CoP trajectory via the pressure distribution mechanism.

Results: 1) CoP and CoM trajectories were perturbed at rotation onset, but baseline CoM trajectories were recovered through emergence of new PD and LU patterns. 2) The variation in the LU pattern was found to have a more dominant effect than PD in countering the effect of the perturbation and restoring baseline trajectory patterns. 3) The model implies that the variability of parameters controlling the LU mechanism is more relevant than the PD mechanism to stability of the system exposed to perturbation.

Conclusions: Collectively, the features and variables of the model provide a way to discriminate passive bio-mechanical effects and active control on 2 dimensional postural trajectory patterns. The architecture of our model helps to explore the interplay of the PD and LU mechanisms on the postural task performance and the underlying structure of adaptive learning.

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Effect of Muscle Strength on Torque Development during Balance Recovery in Standing

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INTRODUCTION: Muscle strength in the lower-extremity is essential to performance of daily life activities including the ability to recover stable upright stance after an unexpected disturbance of balance. Previous studies have also indicated that lower extremity muscle strength training improves the efficacy of balance recovery [1-3]. This study investigated the relationship between ankle torque generated during a maximum voluntary contraction and its generation profile during balance recovery from perturbations in standing.

METHODS: Five healthy young adults with a mean age of 25±1.25 (SD) years participated in this study. Backward support surface translations of velocities from 30 cm/s to 70 cm/s were used to elicit the postural recovery responses of the standing adults. The ankle joint torque in the sagittal plane during maximum voluntary contraction of the dominant leg was also measured by a dynamometer (Kim-Com). A torque generation profile in the sagittal plane during balance recovery from the perturbation was also obtained, including peak torque amplitude following the perturbation, time delay to the peak torque after the perturbation, and the generation rate of the peak torque. The ankle torque during maximum voluntary contraction was entered into linear regression models for parameters of the torque generation profile during balance recovery. Only successful balance recovery trials without taking a step were analyzed.

RESULTS: As you see in Table 1, ankle joint strength was a good predictor of torque generation characteristics in response to support surface perturbations, with torque generation rate consistently showing the highest correlations, especially in the middle range of perturbation speeds.

CONCLUSIONS: Ankle joint strength was a predictor of the ability to recover balance in the median range of perturbation speeds for healthy young adults. This information is currently being used to build a biomechanical model that predicts balance stability by measuring muscle strength during maximum voluntary contraction. The predictive value of the model will be compared to the experimental data. These data suggest that when designing standing balance training programs, therapists should focus on lower-extremity muscle strength training as well as the speed of the dynamic training task.

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Perturbation Speed (cm/s)	Peak torque (Nm/Kg)			Torque latency (ms)			Torque generation rate (Nm/s)		
	R^2	Coefficient	Intercept	R^2	Coefficient	Intercept	R^2	Coefficient	Intercept
30	0.023	-0.0004	1.24	0.166	0.0521	40.30	0.292	-0.8809	175.93
40	0.008	0.0012	1.34	0.273	0.0292	41.92	0.811	2.8251	108.88
50	**0.406**	0.0034	1.30	0.418	-0.0276	43.86	**0.886**	5.6093	56.88
60	0.343	0.0062	1.29	**0.475**	-0.0430	45.22	0.489	4.4755	160.68
70	0.228	0.0061	1.38	0.046	-0.0120	44.37	0.553	4.4772	172.11

Table 1. Regression parameters for maximum voluntary ankle torque to predict peak torque, time to peak torque and torque generation rate during various perturbation speeds.

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Impact of reducing the foot-floor friction coefficient on the passive kinematics of walking

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INTRODUCTION: Falls initiated by external perturbations such as slips are a serious health hazard to older adults. Experimental studies have provided a general description of postural responses to such perturbations. However, causes of failed recovery attempts are challenging to disentangle through experiments alone. Computational modelling and simulation techniques can offer viable alternatives to identify causes of falling. In this study, we investigate the impact of reduced foot-floor friction on kinematics of walking before active corrective reactions are generated.

METHODS: A walking model that included foot-floor interaction, modelled using an array of damped springs with friction under the feet, was utilized to find, using parameter optimization, the set of moments that best tracked the joint angles and measured ground reaction forces obtained from a dry trial. To emulate slippery conditions, forward dynamic simulations were derived by systematically decreasing coefficient of friction (COF) under the leading foot from COF = 1.0 to COF = 0.2.

RESULTS: Preliminary results show that at and during the early stance period (~150 ms) following heel contact on a slippery floor, body kinematics variables were similar to those obtained in the dry condition, indicating the model's ability to generate consistent gait patterns in each case. These simulations are also consistent with experimental results [1]. Later in stance, the simulated kinematics on slippery floors diverge from the dry condition, indicating the need for active corrective moments to maintain balance and to continue the gait task.

CONCLUSIONS: Incorporating these corrective moments in our simulations will be addressed in our future work to investigate the impact of reaction onset and magnitude on the ability to recover from slips.

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New spatial mechanisms for kinematic analysis of the human knee and ankle joints

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INTRODUCTION: In virtually unloaded conditions, the tibiofemoral (knee) and tibiotalar (ankle) joints behave as single degree-of-freedom systems [1,2]. In these conditions, fibres within the ligaments remain nearly isometric throughout the flexion arc and articular surfaces do not deform. Relevant theoretical models are showing that the ligaments and the articular surfaces act together as mechanisms to control the passive joint kinematics. In the knee joint, isometric fibres were identified within the ACL, PCL, MCL ligaments, whereas rigid contacts were associated to the two condylar articular surfaces [3]. In the ankle, isometric fibres were identified within the calcaneal-fibular and tibio-calcaneal ligaments, rigid contacts were associated to the articular surfaces between the tibio-fibular mortise and the talus [4]. Important enhancements have been achieved recently, with more accurate experimental data, more anatomical model surfaces, and more robust mathematical models. This would be useful for a more physiology-based comprehension of human diarthrodial joint motion.

METHODS: Based on experimental observations, the joints were modelled by means of equivalent parallel spatial mechanisms. In general, the models featured two members (i.e. the rigid bone - cartilage) in mutual contact (i.e. at the articular surfaces) interconnected by rigid links (i.e. the ligaments' isometric fibres). Different models having contact surfaces with increasing approximation were analyzed, i.e. planes on spheres, or spheres on spheres, or using B-Spline surfaces. A further series of models, feature two members interconnected by two rigid links and one spherical joint: the low number of members makes this geometrically and mathematically much simpler. Geometrical configuration of these models and validation in terms of comparison between instrumental measurements and model predictions were obtained from experiments in fresh frozen amputated lower limbs, free from anatomical defects. A standard stereo-photogrammetric device was used initially for recording the relative bone motion and for digitizing relevant anatomical landmarks. Passive flexion-extension cycles were performed and relevant data collected. Subsequently, the joints were disarticulated, still with the technical reference frames attached, and articular surfaces and ligament origins and insertions were digitized. Isometric fibre attachment points were determined in the ligament attachment areas and the contact surfaces of the models were obtained by means of best-fit techniques starting from the digitized point clouds. For each model, a bounded optimization procedure was used to find the optimal geometric parameters which allow the different models to best-fit the experimental motion. B-Splines surface positions were not optimized, because of their complexity.

RESULTS: Overall, joint kinematics from model predictions replicated well corresponding experimental measurements. The difference between the experimentally determined and optimally defined ligament attachment points varied between 0.2 and 10 mm. The increase of surface complexity led to a better replica of the experimental joint motion. Mechanisms with the spherical wrist replicated passive motion with a lower precision but with much smaller computational costs.

CONCLUSIONS: The present spatial mechanisms are important means for more physiological mechanical models of both these joints and of the entire lower limb.

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The stabilizing and destabilizing forces: emerging new concepts to assess dynamic stability during functional tasks

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INTRODUCTION: Functional tasks such as walking, turning and getting up are very demanding on stability because of large changes in body configuration and position. When the requirements on stability are too high, the risk of falls increases and may limit the level of everyday activities, particularly in aging population. However, there is no current model of dynamic stability specific for the assessment of dynamic stability associated with various daily activities. The proposed new model combines two emerging concepts, including two theoretical forces, into a single index which quantifies at each instant of the task the overall level of stability of an individual while performing a functional task. The stabilizing force indicates the effort required by the subject to keep his centre of mass inside the base of support. It cancels the theoretical mechanical energy of the body between its current position and the limit of the base of support in the direction of the centre of mass displacement. The destabilizing force is the theoretical force necessary to place the body in an unstable position, i.e. to bring the centre of pressure to the limit of the base of support, in the direction of centre of mass displacement. This force reflects the stability of the instantaneous posture of the body over the base of support. A higher force indicates a more stable posture of the body. The ratio of the destabilizing force to the stabilizing force represents the two forces in a single index of stability. The higher the value of the index, the greater the dynamic stability of an individual during task execution.

METHODS: Preliminary data were obtained by applying this new model in four older adults with different maximal gait speeds. A 3-dimensional gait analysis was conducted to obtain whole-body kinematics, ground reaction forces, centre of mass and centre of pressure displacements during gait at natural and fast speeds in order to compute the two forces and the index of stability.

RESULTS: The results revealed that the destabilizing forces were low during single limb stance and high during double stance period, with similar magnitudes at both speeds. In contrast, the stabilizing forces were high during single limb support and low during double stance period, with magnitudes higher at fast speed than at natural gait speed. Overall, the index of stability was lower during single limb stance than during double stance period, indicating lower stability during single limb stance and at fast speed in particular. In addition, participants with higher maximal gait speeds tended to be more stable (higher index) than the participant with the lowest maximal speed when walking at similar speeds. The latter may emphasize the precarious nature of gait in participants having reduced gait speed.

CONCLUSIONS: This new model of dynamic stability seems promising in evaluating the effort required by individuals to maintain equilibrium during gait. The preliminary data indicate that the model is responsive to gait speed. The model is currently used to compare the requirements on stability of functional activities.

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Gait strategy changes with walking speed to accommodate biomechanical constraints

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INTRODUCTION: Steady state human locomotion at level ground needs compensatory energy input against impulsive energy loss during heel strike. Ground push-off by the stance leg right before the onset of double support phase appeared to be four times energy efficient than the an active hip torque generation during the swing phase [1]. However, if the maximum allowable ankle push-off exists, despite its cost effectiveness, the nervous system may need to employ active hip torque to compensate heel strike energy loss to maintain steady state walking, as similar to the postural strategy changes from ankle to hip strategy to accommodate biomechanical constraints in response to backward perturbation [2]. In this study, we hypothesized that the gait strategy changes from ankle strategy (that compensates heel strike energy loss mostly by the ankle joint push-off impulse) to hip strategy (that generates additional energy input using active hip joint torque during the swing phase) to accommodate biomechanical constraints at ankle joint torque.

METHODS: Eight healthy male volunteers aged 23-27 participated in this study after signing informed consent approved by KAIST IRB. Subjects walked along the 10m walkway with randomly ordered five different gait frequencies given by the auditory cues while having almost constant step lengths. The uniform interval of gait frequencies was obtained by the one third of gait frequency difference between the self-selective and maximum gait frequency. Ground reaction forces of each foot and joint kinematics were measured by two force plates and optical motion capture system, respectively.

RESULTS: The magnitudes of ankle push-offs saturated while those of heel strike impulsive force increased with gait speed. The mechanical energy increase during the swing phase was not significant from zero at the self selected gait speed but significantly increased with gait speed.

CONCLUSIONS: Biomechanical constraints on ankle joint torque was demonstrated by the saturated ankle joint push-offs. Increased mechanical energy during the swing phase implies that the nervous system employs active hip torque to compensate heel strike energy loss to maintain steady state walking despite its higher energy cost than the ankle push-offs. We also suggest that biomechanical constraints induce gait strategy change from ankle to hip strategy, as was observed in the postural control [2].

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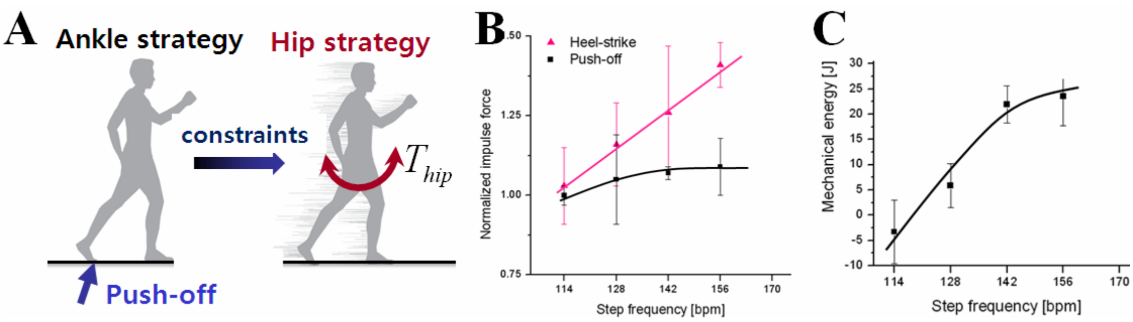

Fig. 1 (A) Hypothesis of gait strategy change to accommodate constraints. (B) Impulsive force of the ankle push-off and heel strike at double support phase. (C) Increase of mechanical energy during swing phase.

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Frontal plane stabilizing moments during assisted walking: older adult assistive device users and beam-walking controls

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INTRODUCTION: The rollator, or 4-wheeled walker, is an assistive mobility device reported to increase walking distance [1], efficiency [2], and reduce knee and ankle torques during walking [3]. Using the wider base of support, the upper-limbs become the predominant effector of stabilizing moments during quiet and perturbed standing in the frontal plane [4]. The aims of this study are: 1) characterize the frontal plane stabilizing moments generated through a rollator during walking under normal and challenged balance (beam walking) conditions, and 2) compare the moments generated by older adult assistive device users with controls. We hypothesized that: 1) the root-mean-square of moments (M_{rms}) and mean vertical load (F_z) generated in beam-walking would be higher than normal walking, and 2) older adult rollator users would generate significantly higher M_{rms} and F_z than controls.

METHODS: Ten (10) healthy young controls (CTL) and 10 older adult rollator users (OLD) participated in the study. Participants walked at their preferred speed with a rollator along a 5m path in normal

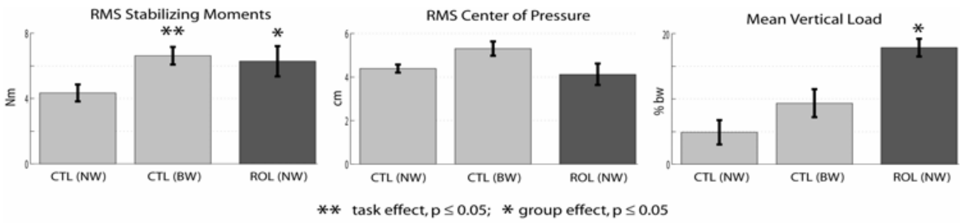

Fig.1 Frontal plane RMS stabilizing moments, RMS center of pressure, and mean vertical load (CTL-controls, OLD–older adults, NW–normal walking, BW–beam

walking (NW). The young subjects group also walked on a 2” beam in the beam walking (BW) task to challenge frontal plane stability. The rollator was instrumented with load cells measuring vertical loads in each leg. Stabilizing moments were calculated as the product of the vertical load on the rollator and the net center of pressure. A two-way ANOVA was conducted to test task and group effects.

RESULTS: Initial results indicate increased M_{rms} ($p = 0.02$) in BW compared to NW but did not significantly increase F_z ($p > 0.09$), partially supporting the first hypothesis. The OLD group demonstrated significantly higher M_{rms} ($p = 0.05$) and F_z ($p < 0.01$) compared to CTL, supporting the second hypothesis.

CONCLUSIONS: The CTL group generated increased frontal plane M_{rms} with the upper-limbs under challenged balance conditions. In parallel, assistive device users (OLD) generated significantly higher moments than CTL, likely achieved by shifting greater load through the upper-limbs onto the walker frame. These findings will impact clinical assessment of balance in assistive device users, evaluate suitability for rollator prescription, and inform device design.

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Joint moments of the lower limb: inverse dynamics versus floor reaction force vector methods

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INTRODUCTION: Lower limb joint moments are routinely used in human movement analysis to evaluate the deficit resulting from pathologies or the efficacy of treatments in terms of joint function. The calculation of three-dimensional (3D) internal joint moments is obtained by means of the inverse dynamics (ID) approach. However, due to the expensive and/or time consuming algorithms related to ID, often simpler methods of estimating 3D joint moments are routinely applied. One of them is the projection of the floor reaction force vector (FRFV). Both methods have intrinsic potential errors. Previous studies [1] simply compared the different estimation of joint moments obtained with the two approaches considering the ID as a reference. The aim of the present study was to investigate, from a biomechanical point of view, the differences between ID and FRFV, in order to give indication in the use of one approach rather than the other one. A case study on an above-knee amputee was conducted.

METHODS: First, in the ID approach, gravitational, inertial, and ground reaction contribution on net 3D internal joint moment were identified. In this way, it was possible to recognize the FRFV estimates in the ID calculations from an analytical point of view. Regarding the ID approach, the lower limb was represented as a chain of three rigid segments (foot, shank, and thigh) and ankle, knee and hip were modelled as spherical joints. Newton-Euler mechanics was applied to each segment starting from the feet. Angular acceleration and velocities were computed using finite differentiation. Inertial parameters were taken from Zatsiorzky after De Leva [2]. Second, normal walking of an above-knee amputee fitted with a C-Leg (Ottobock) reactive knee prosthesis and a Power Knee (Ossur) active knee prosthesis was analysed. Kinematics and kinetics data were acquired using a Vicon (Oxford Metrics) system and two Kistler force plates. For the unimpaired limb the C.A.S.T. technique [3] was applied. For the prosthetic limb specific landmarks were calibrated for the creation of the embedded frames, according to the particular geometry of the prostheses. Internal moments of ankle, knee and hip were analyzed using the above mentioned methods.

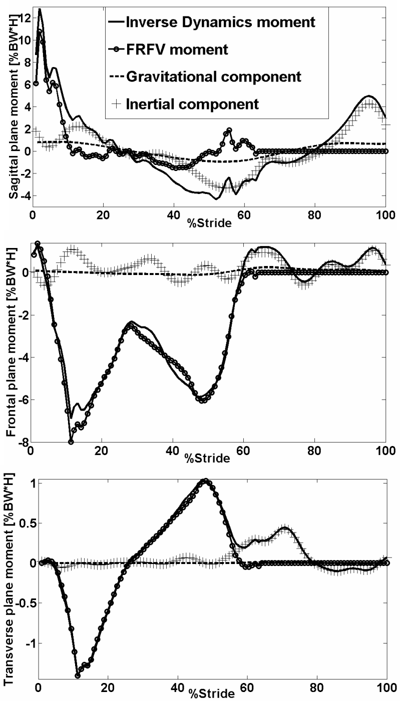

Fig.1 Total, gravitational, inertial, and floor reaction moment in the unimpaired hip.

RESULTS: During the stance phase, the differences between the two methods were negligible in ankle and knee moments of the unimpaired side, with a maximum root mean square difference of 0.44 N*m and 6.86 N*m respectively (sagittal plane). The differences in the hip moment, where inertial and gravitational contribution become more significant, are shown in Figure 1. As FRFV allows to estimate the joint moment only during the stance phase, no comparison can be performed in the swing phase.

CONCLUSIONS: No differences were evidenced from using ID or FRFV method in comparing the unimpaired side of the subject using the two prostheses. On the contrary, the use of the ID method could be potentially more useful in the impaired side as different prostheses have different inertial properties and joint moments during the swing phase became more significant.

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The clinical outcomes of different targets in deep brain stimulation for Parkinson's disease: an interpretation based on a computational model

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INTRODUCTION: We investigated by a computational model of the basal ganglia system (BGS) the different network effects of deep brain stimulation (DBS) for Parkinson's disease (PD) in different target sites in the subthalamic nucleus (STN), the globus pallidus pars interna (GPi), and pars externa (GPe). In particular, our focus here is in disclosing possible interpretations of the clinical motor outcomes observed with different stimulation targets based on simulation results.

METHODS: The model includes a representation of the main stations of the BGS and of the thalamic nuclei downstream to GPi. Each station is represented by a group of Hodgkin-Huxley cell models. The framework explicitly assumes: - the GPe-STN pacemaker hypothesis for the insurgence of PD; - a simplified form of the Action Selection (AS) theory about the role of the BGS, stating that the striatal current to GPi (input) can control the thalamic responsiveness to cortical stimuli (output). Conditions studied were: normal; PD; STN-DBS; GPe-DBS; GPi-DBS. Details can be found in [1].

RESULTS: by analyzing the input-output curves for the different conditions (Fig. 1), results suggest that DBS applied to the different targets could operate in completely different ways, by providing a functional rehabilitation (in the case of STN-DBS) or a functional disruption of the control mechanism provided by the BGS (always "on" during GPe-DBS, or always "off" during GPi-DBS).

DISCUSSION: The results well-match with the few clinical and experimental data comparing different targets for DBS, that state how patients undergoing GPi-DBS show a better control of involuntary, dyskinetic events, while GPe-DBS dramatically augments dyskinetic events (this is the reason why GPe-DBS is not common in the clinical practice). The reason why GPi-DBS provides therapeutic effects despite the shutting down of the output could be explained by considering that other circuits (mainly involving the cerebellum) participate to motor control. Besides the static input-output curves for the different conditions, the model qualitatively allows the modelling of the AS mechanism (in both normal and PD state) and of the L-dopa consumption by assuming they act by dynamically modifying the basal level and/or the range of the input (Fig. 1). Consequently, within the present framework we could relate: (a) bradykinetic and akinetic aspects of PD - to the poor thalamic responsiveness (due to the PD state plus a reduced range of striatal current to the GPi, also hypothesized in PD); (b) dyskinetic events in PD - to the non-zero thalamic activation in the OFF state of a given channel and to the phasic noise entering the circuit by the STN-GPe pacemaker; (c) benefits from L-dopa intake - to a static increase of the range of striatal current to the GPi; and (d) dyskinetic events related to L-dopa intake - to dynamical, uncontrolled modifications in the basal level/range of striatal current to the GPi (leading to uncontrolled activation of the thalamus).

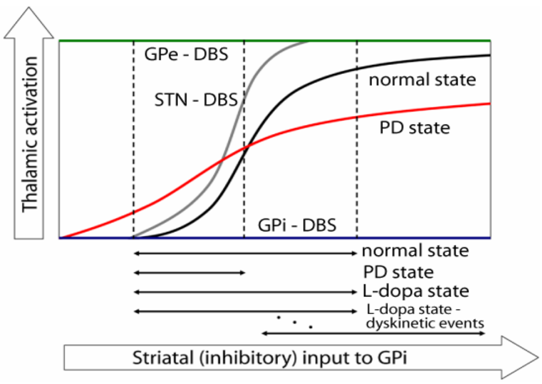

Fig.1 Static input-output curves for the different conditions

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Standardization of clinical stabilometry is a part of posturology

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INTRODUCTION: Communication is at the heart of posturology because, in this field, any postural system disorder is studied as a system dysfunction, not an anatomical disease affecting one organ. Moreover, the postural system is a dispersed system to which numerous organs contribute their input. All organ specialists are invited by the posturologist to apply their professional skills to a work-up, not of their specialty organ, but to how 'their' organ contributes to the postural system. Therefore, communication among specialists is an integral facet of posturology. So, if posturologists try to share stabilometric data obtained with different apparatuses, under different recording conditions, and analyzed with different algorithms, it is obvious that problems will arise.

METHODS: Two measuring instruments can be considered similar if they yield the same metrological performances, regardless of the process used to build them. And it is possible to agree on which instrument performances generate standardized measurements. For example, the French Normalization Committee has proposed that as many distances as possible should be measured between 2 successive sampled positions of the center of pressure, during approximately 1 minute, under such conditions that, for a subject ≥50 kg, 'the maximum permissible error' of evaluation of these distances is 0.1 mm, with a 'resolution' of 0.05 mm. Choosing recording conditions has usually been arbitrary and those that have been used for years should persist. Any new and arbitrary proposal to modify them is unacceptable, but proposals supported by rigorous scientific research should be considered. Indeed, any parameter that function as a logical operator, contributes to the understanding of the phenomenon under evaluation and merits being shared by the posturology community.

RESULTS: The International Society of Posturography recognized the need for standardization and the recommendations, published by [1], were largely followed and helpful. Since 1985, a standardized platform has been proposed; more than 1000 have been built and distributed internationally. Gradually, thanks to this platform, standardized clinical stabilometry is now being used, mainly in France, but also in southern Europe and Russia, where the same values were obtained for conventional parameters.

CONCLUSIONS: Standardization establishes the assessment protocol but does not stop progress. In fact, the great advances made over the last 20 years have been integrated into standardized stabilometry without major difficulties. It is so obvious to us that standardization of clinical stabilometry is an integral part of posturology, thereby making it highly desirable that the ISPGR Standardization Committee, which disappeared at the Houston Congress, reappear in Bologna.

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Nonlinear analysis of posturographic data in de-novo Parkinson's patients

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INTRODUCTION: Aim of this work was the analysis of posturographic data in parkinsonian (PARK) patients at the early stage of the disease by means of nonlinear analysis methods. Comparison with healthy subjects has been done in order to evaluate if such techniques are able to evidence alterations of postural control even at an early stage.

METHODS: Fifteen *de-novo* PD patients (70±9 years, 12 with H-Y=1.0 and 3 with H-Y=1.5), have been tested on a dynamometric platform (Kistler 9281C, sampled at 100 Hz for 60 s), *pre-* and *post-*levodopa assumption. Fifteen control (CTRL) subjects (69±5 years) have been tested too. All subjects have been analysed in eyes open (EO) and eyes closed (EC) conditions. Particular attention has been paid to the methodological issue [1] necessary to estimate, in a reliable manner, the Largest Lyapunov Exponent (LLE); this parameter can be related to the stability of postural dynamics. The nonlinear deterministic nature of the posturographic signals has been verified by means of surrogate data test. After a proper nonlinear filter has been applied, for each time-series the proper time delay and embedding dimension have been evaluated and, finally, the LLE has been estimated.

RESULTS: Figure 1 shows LLE values, mean values (mv) and standard deviations (sd) related to groups of tested subjects.

CONCLUSIONS: Results show that the posturographic signal is chaotic because LLE is positive. *De-novo* PD subjects are characterized by LLE values much higher than CTRL ones that are close to zero. LLE values in *pre*-condition resulted higher than LLE in *post*-condition, thus evidencing the normalizing effect of levodopa. Visual input does not seem to influence LLE. The higher value of LLE in PD patients can be interpreted as an alteration of the dynamic stability and consequently as an increase of the postural instability and can be evidenced since the early stage of the disease. Correlations between LLE and classic geometric and frequency parameters resulted not statistically significant thus

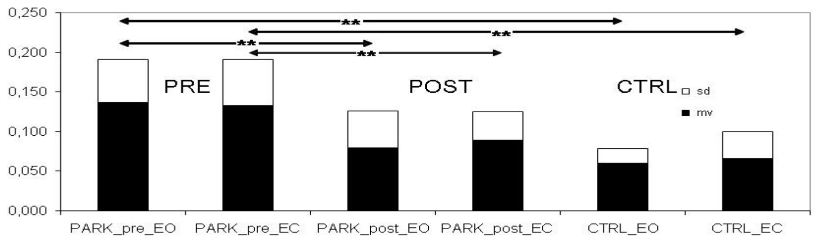

Fig.1 LLE values. (**) means statistical significance (p<0.01)

evidencing that LLE is sensitive to specific central features of the postural system more than to its output, at least as evidenced by the centre of pressure evolution.

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P.157

The Brownian diffusion model revisited in its application to postural sway

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INTRODUCTION: Excursions of center-of-pressure (COP) among normal standing subjects consist in stochastic displacements, limited in amplitude and linked in their succession. Applying the fractal theory of Brownian motions (Mandelbrot and Van Ness) Collins and De Luca showed that the average of the squares of the Anteroposterior (y) sway <Δy> observed during one interval Δt was linked to Δt by a constant of Diffusion D, and generally by a fractional exponent H, the later used as a “scaling factor". Their diagrams of diffusion (<Δy²> as a function of Δt) distinguish a Short Term Region of fast diffusion D1 (H>0.5, Δt < #1s) followed by a Long-Term Region of slower diffusion D2 (H < 0.5, saturating in 10-30 s) The intersection of the slopes valued D1 and D2 is the “Critical Point” P beyond which the postural control system switches from open-loop control to closed-loop control. Our work consisted first to build a software to automatically determine the diffusion coefficient D1 and D2 from the slope of lines drawn to fit the two regions of the plot curve. It appeared that the Brownian diffusion diagram was topologically equivalent to the auto correlation (AC) profile for the same movements of the COP (fig. 1). This similarity motivated us to propose an original interpretation of the D1, D2 regions, and of the significance of P.

METHODS: Our self made software was applied to Y displacement of the COP recorded from young normal adults. The force platform used was built in the laboratory according to the French stabilometry normalization (AFP 40/16). The sampling rate was 40Hz with 51.2s recording duration. The diagrams of Diffusion and AC have been compared.

RESULTS: The diffusion and AC profiles are almost identical, except for sign and an add constant value (two times the variance of the stabilogram). The coefficient of inter correlation is 0.98. For a given stabilogram, the analysis of the two profiles produced the same values D1, D2, and the same critical point coordinates (fig. 1).

CONCLUSIONS: Our analysis program enables us to identify, on the AC profiles, the same parameters as the ones measured by Collins and De Luca. However, our AC interpretation places more emphasis on notions related to signal internal dependency, system memory, signal regularities, etc. The way we characterize AC function does not exclude the possible existence of two processes, namely an open and a closed loop one acting before and beyond a critical point. Still, this interpretation does not appeal much to us. Referring to AC and its characterization, we propose a marker of the system memory which is also a critical delay for which the autocorrelation coefficient is nil (first zero-crossing). An exponential fitting function of AC, such as the curve describing a capacitor discharge, allows to extract the system time constant (AC=0.37) and the slope at the curve origin. That slope, in fact, determines the deceasing speed of the AC function.

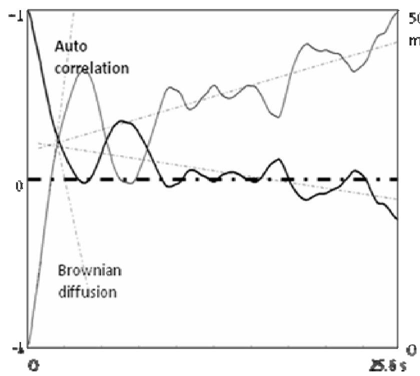

Fig.1 Compared profiles of AC and Brownian diffusion.

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Variability and repeatability of postural parameters at norm at different conditions of research

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INTRODUCTION: The problem of variability and repeatability of stabilometric parameters and their clinical use remains indefinite in literature; results of investigations of different authors are rather contradictory. Some authors pointed a very insignificant repetition of stabilometric parameters [1] the others ones found teaching effect during the protracted session of investigations [2]. The research of [3] defined that parameters have different variability.

METHODS: 37 healthy adults at age of 20 to 50 years old (average age 34.92±2.0 years) among which there were 14 men and 23 women were surveyed. Stabilometry investigation and BFB of the groups was taken by Stabilometry system from MBN Company (Moscow, Russia). Registration was during 51 second in each state – with eyes open (EO) and eyes closed (EC). Feet were placing together during testing. The investigation was made at a few trials. One trial was just one time investigation. Next trial included consistent registration with 3-7 minutes time period. A day trial investigation was made by everyday stabilometry investigation for each person during 12 days.

RESULTS: The results of the investigation of variability of postural parameters in the group at first trial of investigation, shown that in spite of high magnitude of the coefficient of variation, they are stable and have chaotic type of variability. Deprivation of vision practically does not influence on variance of stabilometric parameters in the investigated group of healthy people, that indicates high stability of postural system. Stabilometric parameters didn`t change during the investigation with short period of time and showed high periodicity and stability. The repetition of stabilometric parameters during daily investigation showed very low level.

CONCLUSIONS: So a defined conclusion can be done, that parameters with high coefficient of variability do not possess repeatability, as it was found for the investigation with short period of time. Analysis of Romberg coefficient (at day trials) showed a phenomenon of changing of the priority of sensory system in the process of holding of static balance. So, the correlation of balance of visual and proprioceptive systems at norm can change in noticeable limits in dependence of demands of external and internal environment of an organism, up to change of dominant sensory system in stabilization of vertical state.

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Basic law of oscillation of center of pressure, could we use it at clinical decision making?

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INTRODUCTION: The body of an upright standing man performs oscillations around some middle position. Oscillations of Center of Pressure (CP) in frontal and sagittal planes are subjected to certain regularity that is known as I\f noise. Subjection from this law of oscillations of CP is found in researches [1,2]. As a matter of fact 1/f noise is known and reveals in different fields of techniques, physics and biological processes. Nevertheless, the possibility of using that regularity of forming of oscillations of CP for clinical analysis remains unclear.

METHODS: Groups of adult healthy persons (56 subjects) and patients with deep right-side hemiparesis (54 patients) and frontier mental pathology (30 patients) took part in the investigation. Healthy adults – two groups with different feet placing were investigated. Feet placing with European standard [3] – 26 subjects and “feet together” position (30 subjects) were used. The investigation for the group of patients with deep right-side hemiparesis was carried out in accordance with European standard. Stabilometrical investigation of the groups was taken by Stabilometry system from MBN Company (Moscow, Russia). Registration was during 51 second in each state – with eyes open and eyes closed. The main interest was at the analysis of first three by size amplitudes and corresponding to them frequencies of oscillations.

RESULTS: All investigated groups showed strong regularity (statistically significant) at frequency analysis of oscillation of CP at frontal and coronal plane. The lower the frequency of oscillation, the higher it`s amplitude and accordingly, the higher frequency of oscillation, the lower it`s amplitude. Some patients have a different result when some oscillation which has higher frequency shown more amplitude.

CONCLUSIONS: Thus, the analysis of findings, as in groups of norm so as in groups of patients, allows to conclude: oscillations of CP in coronal and frontal plane are submitted to the basic rule – high-amplitude oscillations are low- frequency and low-amplitude – are high-frequency. This regularity is based on physical nature of the process of oscillation. If for normal groups that character of oscillations is physiological, so for groups of patients, where balance is initially abnormal, the discovered consecution of oscillations and their frequency may occur in case of successful, physiological compensation. This condition occurs far from always. That is why, if oscillations of CP do not conform to regularity, described above, so we can regard this condition as a disturbance of natural compensatory processes.

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Presence of two-scaling regions in DFA plots of 60 second quiet-standing

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INTRODUCTION: Two common fractal analysis methods used for center of pressure are Stabilogram Diffusion Analysis (SDA) and Detrended Fluctuation Analysis (DFA) [1]. SDA results show two scaling regions, suggesting two modes of control for different time intervals [2]. These findings have been contested as a statistical artifact due to the assumption of an unbounded COP data series [2]. DFA has been a recommended substitute, as it is not subject to this artifact because it cumulatively sums the data [2]. Published DFA results show only a single region, likely for this reason [1,2].

METHODS: 150 subjects aged 65 – 97 participated in a study to examine the postural sway differences between fallers and non-fallers. Subjects performed four quiet-standing trials on a force-measuring platform: Eyes Open, Comfortable Stance; Eyes Closed, Comfortable Stance; Eyes Open, Narrow Stance; and Eyes Closed, Narrow Stance, in a randomized order. Data was collected for 60 seconds at 1000 Hz. DFA was applied to COP data to calculate A/P and M/L α-scaling exponents. The DFA plots did not reveal the expected single linear region to be fit by a single α-scaling exponent.

RESULTS: Two unique regions, as shown in Figure 1, stood out for all testing conditions. Best-fit lines, as shown in Figure 2, were fit to the data to report two scaling exponents. For non-fallers, the average α was 1.79 ± 0.06 for the short-term region, and 0.96 ± 0.24 for the long-term region for the M/L direction, Eyes Open, Comfortable Stance. The average crossover point was 3.15 ± 0.24 (1.41 seconds). There were no statistically significant differences between fallers and non-fallers and trends were similar for all conditions and in both sway directions.

CONCLUSIONS: These findings suggest that two scaling regions are present in DFA plots of sufficient time duration. An anti-persistent trend is observed in the short-term. A persistent trend is suggested in the long-term, though results were limited by the small amount of data in this region. The similarity to the contested SDA method is notable, encouraging further review and comparison of the two methods.

ACKNOWLEDGEMENTS: We wish to thank Dr. Thomas A. Adams II.

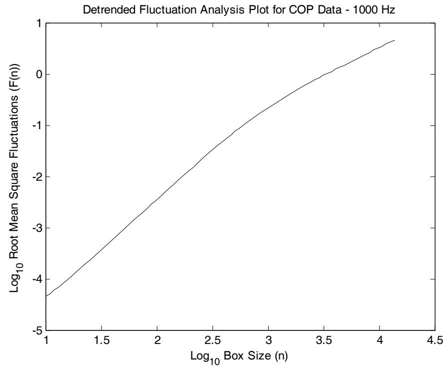

Fig.1 Representative DFA Plot for 60 second quiet-standing COP data

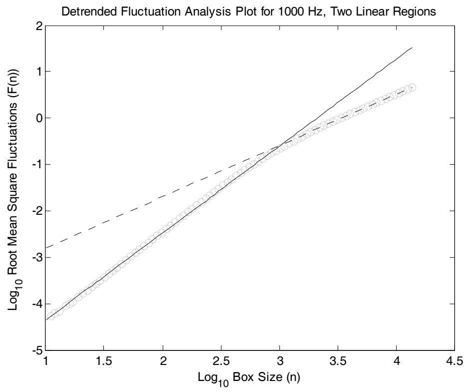

Fig. 2 Representative Plot of DFA plot analyzed with two regions

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Measurement of the scapular profiles by the fringe projection Moiré technique

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INTRODUCTION: The assessment of the scapular kinematics is difficult due to its peculiar feature of sliding under the skin, making the use of systems that require surface markers difficult [1]. The most commonly employed methods [1], such as electromechanical and electromagnetic systems are costly, have low clinical applicability and, in some situations, do not allow precise analyses. The Moiré projection technique (MPT) has some advantages over the commonly used methods, since it does not require physical contact, is composed of simpler and more robust optical components and, therefore, may be more applied to clinical contexts [2]. The aim of this study was to investigate the applicability of the MPT to quantify the scapular kinematics.

METHODS: Six healthy subjects without shoulder complaints were evaluated. The optic-mechanical setup of the proposed system consisted of a digital camera (2048 X 1532 pixels), positioned at the L_k distance and a LCD projector (1024 x 768 pixels), positioned at the L_p distance from the surface. Four fringes were projected on the studied surface (scapula) and four on the plane surface (reference). The fringes were projected with a displacement of one quarter of a fringe between each, thus causing a mutual phase shift of 90^o. The images were captured and stored automatically on the computer by dedicated software. By simple subtracting of the reference value from the scapular phase maps, the phase map due to the Moiré fringes could be digitally obtained. After the phase unwrapping, the 3D profile could be automatically obtained without prior information of the object. The calculations of the scapular kinematics were carried out with procedures developed at *MatLab®* using the tridimensional data obtained from the phase displacements.

RESULTS: Scapular kinematics obtained with the MPT is show in figure 1.

CONCLUSIONS: Due to the importance of analyzing the scapular positioning in clinical contexts, greater efforts need to be undertaken to develop methods that allow a quantitative 3D analysis of the scapular kinematics. The MPT allowed the scapular 3D measurements to be obtained in a digital, automatic, and non-contact manner, with only 5% of uncertainty. The disadvantage was that the phase displacement method did not allow true dynamic analyses, since it requires that several fringe patterns be projected on the object before it moves. Nevertheless, the use of the MPT may be an attractive choice to analyze the scapular kinematics, since it provides the 3D deformation of the surface, without need of surface markers. In addition, it is fast (30 minutes), low cost, precise and showed to be robust to be used in both research and clinical contexts.

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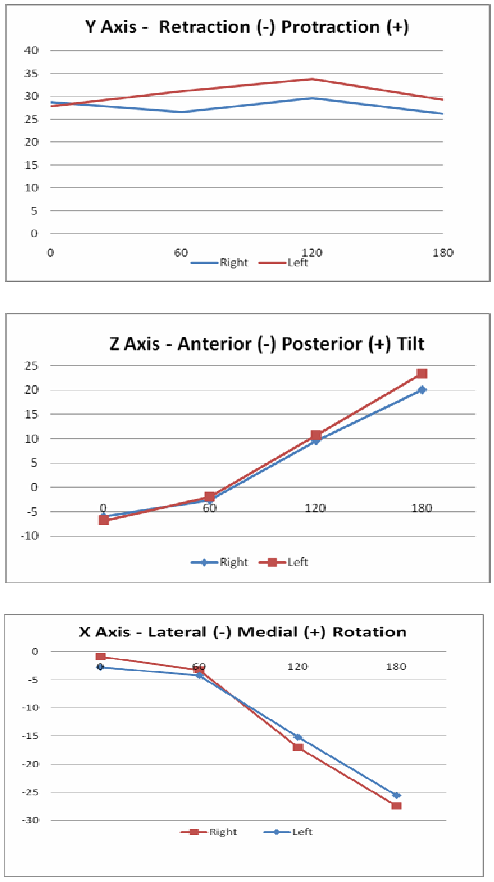

Fig. 1 Scapular Kinematics: a) Retraction and protection; b) Anterior and posterior tilt; c) Lateral and medial rotation

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The 3-D trajectory of the body center of mass during walking. Normative parameters from adult human walking on instrumented treadmill

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INTRODUCTION: During standing, the projection of the body centre of mass (CoM) onto the ground surface must oscillate within the base of support. Clinical deficits of balance may be inferred by analysing the 2-D trajectories of the centre of pressure recorded through static force plates (so called posturography). Balance is even more crucial to walking. However, the 3-D trajectory of the CoM has been little investigated. Studies were based on modelling of anthropometric and kinematic data recorded through lengthy experimental sessions. A direct measurement of the CoM motion can be obtained from the analysis of ground reaction forces, as long as entire strides are performed on long force platforms (so called "Newtonian", or Cavagna's method) [1]. A treadmill mounted on 3-D force sensors makes testing very brief, as long as several subsequent strides can be recorded at known and constant speed in a few seconds. Normative data, providing the basis for clinical application of this method, are still missing.

METHODS: Sixteen healthy adults (20-55 yrs, 8 women) were enrolled. They were required to walk on a treadmill mounted of 8 piezoelectric 3-D force transducers. The method has been described elsewhere, and it was proven to provide force records comparable to those obtainable from ground walking [2]. Six subsequent strides were analysed per each subject. Successive walking runs at 9 progressive speeds over a 0.3-1.4 m s^{-1} range were required.

RESULTS: the trajectory of the CoM during a stride has a smoothed “rabbit's ears”. At low-intermediate speed (around 1 m s^{-1}) the “ears” are each oriented 45° to the vertical, the CoM path over the stride is 25 cm long and it is encased in a 40 cm^3 displacement volume, approximately. As a function of speed, the wings progressively orient to the vertical, the CoM path declines while the encasing volume undergoes minimal or no changes. The jerk (1st derivative of acceleration) of the CoM path was computed, both *per* stride and normalised to the path length. Both of these parameters increase remarkably as a function of speed. In all respects, the left and the right wing are mirror images. The compliance of the CoM trajectory with the 2/3 power law of movement (rotational speed being proportional to $curvature^{2/3}$) [3] is presently under scrutiny.

CONCLUSIONS: the results provide a normative basis for the analysis of the trajectory of the CoM during walking, as a potential clinical index of balance and stability.

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Detection of regularity sway of the gravic body sway. Comparison of the example of normality, vestibular neuronitis, bilateral canal paralysis, cerebellar lesion and spino cerebellar degeneration (SCD)

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INTRODUCTION: The sway of the body at the time of human standing posture is a phenomenon, which happens by repetition of a righting reflex. Research has been advanced about regularity being in the sway at the time of the postural control at this time. It compared about the change of sway when being accompanied by an obstacle with existence of the frequency where normal sway was stabilized**.**

METHODS: Frequency divided the zones up to 0.02 to 10Hz into 512 bands about 153 normal cases, 34 vestibular neuronitis cases, 36 examples of a bilateral canal paralysis, 19 cerebellar lesions, and 35 examples of SCD, and the FFTpower of each frequency was analyzed. The coefficient of variation (CV) compared variation for the FFTpower of each frequency band. The normal example chose the example of 0.7 or less CV and others as significant in 0.6 or less.

RESULTS: In the vestibular neuronitis, the frequency band stabilized in high frequency in eyes open and the eyes closed of lateral body sway was shown. In antero-posterior sway, it was a result with few frequency bands, which were stabilized as for eyes open, and eyes closed. The example of a bilateral canal paralysis showed the frequency band with little variation in 5Hz-7Hz of frequency about lateral body sway and antero-posterior sway. However, 2 to 5 Hz showed the frequency band with large variation. The example of a bilateral canal paralysis has the sway stabilized in comparatively high frequency. The cerebellar lesion had a low frequency region of a coefficient of variation in the large zone.

CONCLUSIONS: In order to find the constancy of sway for every disease with a normal person, the frequency band of the stable sway has been searched. As a result, having a frequency power zone with little variation in each also according to the obstacle was shown. Catching the feature from which postural control changes with the differences in an obstacle that the diagnosis of a disease was attained thought it

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Defining a set of stance tasks in progressively increasing difficulty using time domain posturographic measures

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INTRODUCTION: Different stance tasks have been used in literature to demonstrate the effect of vestibular biofeedback. Obviously, the impact of biofeedback will depend on the challenge of the task which differs among patients. The main purpose of the present study was now to define a set of stance tasks with progressively increasing difficulty. Moreover, we investigated which time domain measures can successfully discriminate stance established during the various tasks. We also compared the measures as derived from a force platform (COP detection) and a triaxial accelerometer (L3 movement detection). This set might be used to investigate the effect of vestibular biofeedback in an individual subject's most challenging task.

METHODS: 11 healthy subjects (age 22-29, 4 male, 7 female) performed 8 different stance tasks with increasing level of difficulty on a force platform (Maastricht Instruments BV, sampling frequency 25 Hz, resolution 0.01^o) and synchronously with a triaxial accelerometer (McRoberts, Dynaport MiniMod, sampling frequency 100 Hz, 1 mG (minimum 0.06^o) resolution) at L3: standing with eyes closed and bare feet for 45 seconds on a 1. firm surface, feet at hip width, 2. firm surface, feet closed, 3. foam surface (Airex Balance-Pad 6 cm), feet at hip width, 4. foam surface, feet closed, 5. firm surface, semi-tandem stance, 6. firm surface, tandem stance, 7. foam surface, semi-tandem stance and 8. foam surface, tandem stance. Swaypath, swayarea, mean sway (AP, ML and along the vector) were calculated. Within subject analysis between tasks was performed using Wilcoxon's signed ranked test with Bonferroni correction (p<0.01) for multiple parameter testing.

RESULTS: Based on the median values and statistical analyses, the final set of stance tasks found was 1-2-3-4-7-8. Swaypath derived from the force platform was the only measure to show significant differences in stance between these 6 tasks. Derived from the accelerometer, swaypath showed significant differences in stance between all tasks except for one (between tasks 4 & 7). Swayarea and mean sway along the vector showed significant differences in stance between all tasks except for one, derived from both the force platform and accelerometer. Swaypath showed the smallest inter- and intra-individual variation of the investigated measures (see Fig. 1).

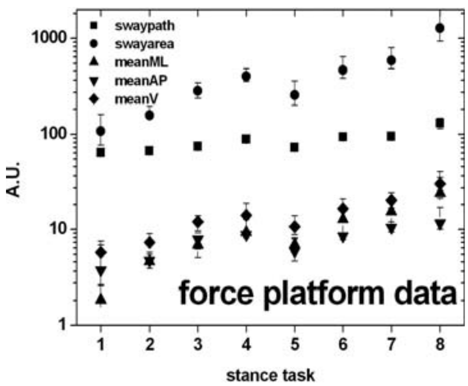

Fig. 1

CONCLUSIONS: All calculated measures from the force platform and the accelerometer result in a consistent level of difficulty for the stance tasks in the final set. However, swaypath, swayarea and mean sway along the vector are most successful in differentiating between conditions representing progressive challenges to balance control. Swaypath was the only measure to show significant differences in stance between all tasks of the final set. This has been stated in literature before [1,2,3]. Moreover, swaypath showed the smallest variations. So, swaypath seems to be the preferred measure in clinic for posturographic assessment and as a measure to evaluate training or the effect of vestibular biofeedback.

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Drag percent: an alternative approach to estimating stance timing when gait is impaired

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INTRODUCTION: Traditional measures of stance and double support percent (stpct, DSpct) are widely used for quantifying gait. However, when gait is altered with disease or advanced aging, irregular walking patterns such as shuffling or freezing of gait may make it difficult to determine the end of the stance phase and hence gait cycle timing. In order to estimate the timing of stance in the presence of impaired gait, we propose an alternative approach, based on the time the foot "drags" along the floor and introduce two related measures: Single Drag Percent (Sdpct) and Double Drag Percent (Ddpct) for evaluating stpct and DSpct, respectively. Here we describe the relationship of these new parameters to the traditional measures in healthy older adults and in patients with advanced Parkinson's disease (PD) who underwent Deep Brain Stimulation (DBS) surgery and their sensitivity to different conditions.

METHODS: The first data set included recordings from 216 healthy older adults (mean age: 76.6±5.8: range: 70-90 yrs, 128 women) who walked for 2 minutes back and forth along a 25 meter long corridor. This task was repeated under dual task

(DT) conditions (i.e., phoneme monitoring, serial 3, and serial 7 subtractions). The second data set was from 35 PD subjects post DBS (mean age 63.2±8.5 yrs; 6 women; mean UPDRS-motor score: 37.1±14.6), who walked 1 minute with the DBS turned off and while off anti-parkinsonian medications (off/off), and with DBS turned on while on medications (on/on). All subjects wore force sensitive insoles (with 4 "switches") placed inside each shoe. Drag percent measures were obtained by dividing the data into 1 second epochs and calculating the percentage of time in which the relevant sensors were activated. To assess concurrent validity of this new approach, we compared the new and traditional measures using intra-class correlation coefficients [ICC(3,1)]. To assess the possible benefits of the new approach and the sensitivity of both methods to different conditions, we applied paired t-tests.

RESULTS: The new method was successfully implemented on problematic trials that were not properly handled by the traditional approach (i.e., where end foot contact times could not be reliably detected). These trials were excluded when the two approaches were compared. The ICC's generally indicated moderate to high levels of correlation for Sdpct and Ddpct. For example, for the healthy older adults, ICC's for Sdcpt were 0.85, 0.90, 0.83, 0.86 for all trials, usual-walking, serial 3, serial 7 subtractions, respectively. In the patients with PD, ICC's for Sdpct were 0.73, 0.81, 0.71 for all trials, on/on, and off/off, respectively. In the healthy subjects, both the traditional and new measures identified significant increases in support time ($p<0.001$) when comparing S7 to usual walking and both gave non-significant results in test retest trials. In the DBS patients, both the traditional and new measures failed to detect significant differences in Ddpct or double support between on/on and. off/off. However, when trials that were originally excluded by the traditional filter were included, the new measures indicate that support time was significantly reduced in the on/on condition (from: 43.6±15.4% to 36.5±8.9%; $p<0.02$).

CONCLUSIONS: Drag percent measures provide an alternative approach to quantifying support timing in the presence of problematic data such as those that may be caused by shuffling and advanced Parkinson's disease. A key advantage is that there is no need to identify toe-off or end contact time for each stride cycle. The present findings demonstrate that results based on this new method are meaningful and may be more sensitive to changing conditions than the traditional approach.

ACKNOWLEDGEMENTS: This work was supported in part by the NIH (AG14100) and the European Commission in the context of FP6 projects DAPHNet, fet-018474-2, and SENSACTION-AAL, infso-ist-045622.

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Measuring knee skeletal internal/external rotation with skin markers

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INTRODUCTION: In all protocols for gait analysis [1-3], the reliability of three-dimensional knee rotations still remains an issue. The aim of this study was to evaluate experimentally in-vivo this error in different protocols and marker sets. Several multi-marker clusters, including physical markers and calibrated landmarks, were analyzed during gait and elementary exercises. The addition of a few markers to the standard sets was hypothesized to enhance skeletal knee rotation tracking.

METHODS: Six male volunteers (means: 33 years, 79 kg, 176 cm, BMI 25.14) were instrumented with a marker set combining 3 standard protocols [1-3]. These were tracked (Vicon Motion Systems, UK) in up-right posture, level walking, knee flexion/extension (FE_knee) and hip flexions/extensions combined with ab/adductions with the knee in full extension at different angles in the transversal plane (STAR_hip). In addition to the standard protocol-based analyses, other techniques were utilized for knee rotation calculations, by using the same femur anatomical frame [2] and same joint convention [5]: addition of a medial epicondyle (ME) marker, and technical frame calculations by increasingly larger thigh clusters for SVD-based [4] reconstructions of anatomical landmark trajectories. The hip joint center was always taken as defined by regression equations [6]. Error is calculated as the difference between expected physiological and measured range of motion.

RESULTS: In all subjects, large erroneous values in internal/external rotation were found by all techniques. In walking and STAR_hip, the clusters with the ME marker showed the largest probability for the error to be below the average (about 70%, in Fig. 1). The single best estimation of internal/external rotation was obtained by adding the ME marker, though this is not viable in all subjects and not true for every motor task. In walking, the error from the cluster with all markers is one fifth of that from the worse cluster. The markers in the distal thigh reduced the error to about 50% in all tasks.

CONCLUSIONS: Skeletal knee rotations can be fully mis-tracked when calculated from standard marker-sets. Erroneous knee internal/external rotation is as large as 55 degrees, though obtained for isolated and very large thigh rotations, not exercised in daily living activities. Important reductions of this error can be obtained by including additional markers at the central and distal areas of the thigh. A ME marker or a few additional markers on the distal thigh reduce the errors to a large extent.

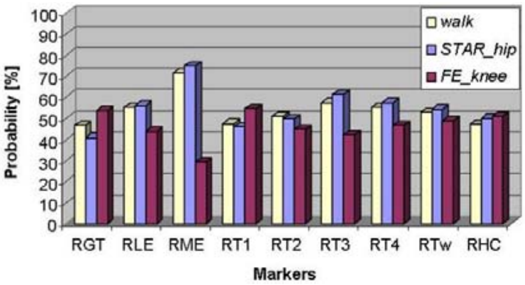

Fig. 1. Probability to remain below the mean error using each of the available markers.

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P.168

Detection of a turn while walking based on curvature-velocity analysis

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INTRODUCTION: A fundamental question arises to understand curved walking: how to determine accurately and automatically whether a subject is actually turning? Several methods were proposed for human locomotion using manual video analysis [1], deviation in the direction of progression [2] or a predefined trajectory drawn on the floor [3]. We aim to identify which steps are performed while turning within a natural path.

METHODS: The hypothesis of this study is based on a potential relation between mean curvature (C) and mean velocity (V) for each step in straight walking allowing to identify a set ε of couples [V,C], specific of straight walking. Then, for a given trajectory, a turn could be detected if one or several couples [V,C] associated with a step is out of this set ε. Fifteen subjects were asked to walk along a straight line and 10°, 20° and 30° turns, at natural, slow and fast speed. For each condition and each speed, they achieved this motion four times. 3D kinematic data were recorded thanks to twelve Vicon MX cameras (Oxford Metrics®, UK) at a sampling rate of 120Hz. Trajectories were segmented step by step using heel strikes detection algorithm. We computed C and V of the centre of mass trajectory for each step of each trial. The sign of C is positive when curvature is on the left (resp. right) after a right (resp. left) stance, which corresponds to a straight walking behaviour, and negative otherwise.

RESULTS: The relation between couples [V,C] for all subjects and all trials in straight walking can be expressed in the log-log space (fig. 1a). A linear relation was found between log(C) and log(V) (R^2=0.56, $p<0.001$). A 95% interval of confidence, illustrated in dark grey in figure 1a, can be determined in order to characterise a global behaviour in straight walking. This 95% interval of confidence could then be transformed in the initial space [C,V] (fig. 1b). If a couple [C,V] goes outside the interval of confidence, this indicates that the subject's behaviour differs from straight walking. We then studied curved trajectories with respect to this straight walking behaviour. Results showed that for 10°, 20° and 30° turns, 68.9%, 96.7% and 100% of turns were respectively detected. The method to define whether and when a turn occurred is then accurate since only 3.3% of turns were not detected in a 20° turn that is a small direction changing.

CONCLUSIONS: The method was able to detect a turn for natural walking trajectories. We could then characterize the stepping strategy. Indeed, turns can be performed using the outside foot which corresponds to an amplification of the curvature above the set ε or using the inside foot meaning a negative curvature under the set ε. We noticed that most of the turns were performed using a multi-steps strategy.

ACKNOWLEDGEMENTS: This study was funded by ANR-Locanthrope project.

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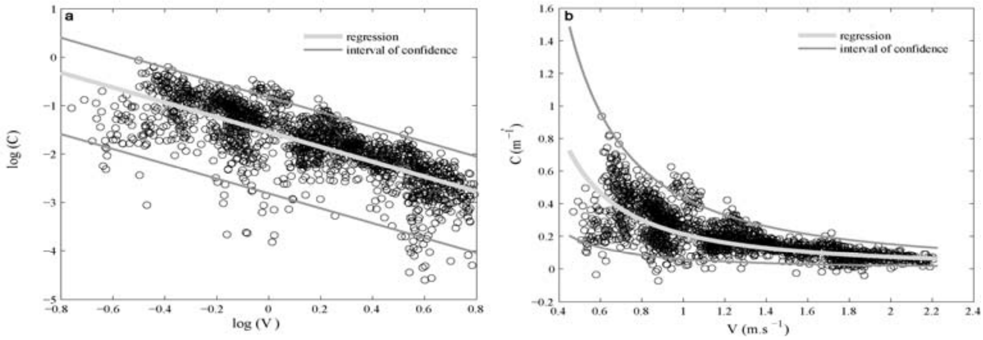

Fig.1 Relation between curvature and velocity for straight walking: in log-log space (a) and set ε of characteristic behaviour (b)

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Does a specific visual target improve the reliability of postural stability measurements?

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INTRODUCTION: Visual information is important for postural stability especially under more challenging environment constraints. However, many studies that measure postural stability do not mention the use of a visual target and it must be assumed that no specific visual target was used. The purpose of the study was to determine if standing postural stability measurements are made more consistent and reliable by fixating a specific visual target rather than using visual cues available in a typical gait lab.

METHODS: Fifteen healthy older adults (75.3±5.0 yrs) stood, barefoot, as still as possible on a 1.8 cm thick piece of foam placed on top of a single force-platform for 60 s. Subjects placed their feet at a distance of 11% of their height apart, with their feet externally rotated by 15º (McIlroy & Maki, 1997). Data were collected with the head straight ahead and tilted at 45º under 3 visual conditions: 1) Target (black cross on a white background) at subjects' eye level (1m in front); 2) No target, cluttered visual scene (1.5 to 4m from viewer). This consisted of part of the lab filled with unused equipment and 3) No target, uncluttered visual scene (1.5m from viewer). This consisted of a plain light-grey boarding giving minimal visual cues. The trial order was fully randomised, with three repetitions for each condition. Data were analysed for the middle 40 s of each trial, with data obtained for the first and last 10 s of each trial excluded from the analysis. Postural stability was defined as the standard deviation (SD) of the AP excursions of centre of pressure (CP) about the mean. Consistency of postural stability was defined as the variability in this measure across repetition.

RESULTS: Compared to standing with the head straight ahead, AP SD was significantly increased when the head was titled ($p < 0.05$). Regardless of head orientation, subjects demonstrated significant decreases in AP SD when fixating the target compared to all other visual conditions ($p < 0.001$) (see Fig 1a), and consistency of postural stability was significantly better when subjects fixated the visual target compared to all other visual conditions ($p < 0.05$) (see Fig 1b).

CONCLUSIONS: These preliminary results indicate that postural stability measurements were more consistent when fixating a specific visual target as illustrated by the increase in inter-trial postural stability consistency compared to when no target was available. These findings suggest that providing a specific and simple (high contrast) target is necessary when controlling for the visual contribution to postural stability. Further analysis of test and retest postural stability with and without a specific visual target will provide vital information concerning the reliability and discriminative ability of such measurements between young adults and older adults at low- and high-risk of falling.

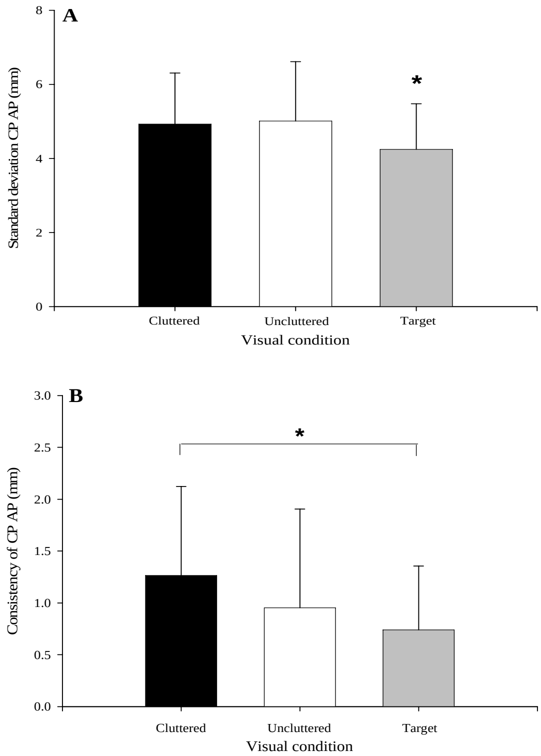

Fig. 1. A) SD CP AP excursion (mm) under the different visual conditions, and B) Consistency of CP AP excursion (mm) under the different visual conditions.

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Assessment of gait stability and variability in humans and bipedal robots

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INTRODUCTION: Humans are able to walk on irregular surfaces and avoid falling even in the presence of unexpected perturbations. However, this is still a challenging problem for bipedal robots. It is remarkable that bipedal robots, unlike humans, are unable to walk in non-structured environments and to cope with unexpected perturbations. The success for perturbation rejection in humans relies on: 1) a fast and accurate detection of perturbations [1] either internal or external, like tripping on a curb; 2) and to select an adequate reaction based on several factors like, sensory information, previous experience, muscular condition, perturbation suffered. The goal of this work is to present a method to analyse human walking stability based on an algorithm designed to analyse bipedal robot stability.

METHODS: The proposed algorithm observes continuously the state of the walker [2], human or robotic and, if an unexpected event happens, a measure of the deviation to a reference walking cycle exceeds a certain boundary. This method has been successfully employed to detect trip and push perturbations in robots with a delay comparable to short-latency reflexes.

RESULTS: An example of the application of this method to detect a push on the trunk of a biped robot while walking is illustrated in Figure 1. The upper panel shows how in the normal stride the nearest neighbour (NN, dashed line) follows the reference (solid line), whereas the NN deviates from the reference in the perturbed stride. It can be observed how the algorithm provides a measurement of the deviation (D-statistic on the lower panel) that is fast and robust.

CONCLUSIONS: A method to quantify and evaluate deviations from a reference walking pattern in biped robots and humans is proposed and validated. Further work extending the application of this method to evaluate pathological human gait patterns is guaranteed.

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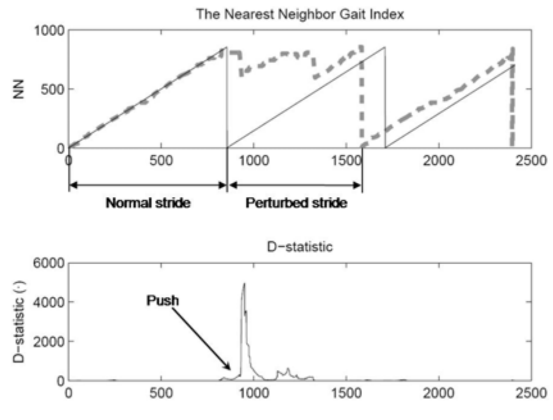

Fig.1 Detection of a push on the trunk of a biped robot.

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P.171

Swing and stance time asymmetry in self–selected and in fast walking speed in healthy adults

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INTRODUCTION: With all conditions equal, it is logical to assume that asymmetrical gait is associated with lower gait speed than symmetrical gait. In fact, the characteristics of the relationship between the fastest attainable gait speed and gait symmetry have not yet been determined. Therefore, the purpose of this pilot work was to get insight into the relationship between asymmetry and gait speed in healthy young adults.

METHODS: In order to impose gait asymmetry a load of 3.0 kg was attached to the distal end of the right leg above the ankle joint, similar to the method applied by Smith and colleagues [1]. Temporo-spatial gait variables were measured in 22 healthy volunteers (11men and 11women), aged 27.2 (±3.1) years during an indoors test. Each participant was tested while walking on the GaitRite walkway under four randomly ordered conditions: 1) Self selected speed without load (SS) 2) Fast speed (subjects were encouraged to walk at their fastest speed), without load (F). 3) Self selected speed with the right leg loaded (SSL). 4) Fast speed with the attached load (FL). Three repetitions were performed per condition with mean values representing each variable. Data were analyzed offline. Asymmetry index (SI), for the variables of "swing time" and "stance time" was calculated by the formula [((R-L)/0.5*(R+L)) *100].

RESULTS: Subjects' gait speed (mean ±SE) during the SS, F, SSL and FL conditions was 1.4 (±0.04), 2.7 (±0.07), 1.4 (±0.04) and 2.6(±0.07) m/sec, respectively. Mean absolute symmetry index values (SI) for stance and swing times are presented in Table 1. The added load increased both swing and stance asymmetry. Since a positive index pointed to greater swing and stance time for the right loaded leg than for the left leg (and vice versa for a negative index), the number of subjects (n) with either a positive or negative index is also provided in the table. It can be learned from the table that in the majority of the subjects swing time of the right leg increased when loaded while stance phase time decreased in both speeds.

Speed Condition	Swing SI	Negative Swing SI (n)	Positive Swing SI (n)	Stance SI	Negative Stance SI (n)	Positive Stance SI (n)
Self Selected	5.09 (1.2)	13	9	3.58 (0.70)	8	14
Fast	4.27 (1.04)	11	11	9.9 (2.73)	10	12
Self-Selected Loaded	8.13 (1.18)	3	19	5.14 (0.56)	20	2
Fast Loaded	8.13 (1.55)	8	14	8.94 (1.49)	17	4

Table 1: Mean Absolute (±SE) Symmetry index (0 = completer symmetry)

CONCLUSIONS: The findings are relevant for gait characteristics of patients with one lower limb pathology such as patients walking with a cast or brace. They point to an increase in swing time and decrease in stance time of the loaded limb; for short walking distance indoors, these changes do not appear to effect gait speed.

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Automatic detection of postural sway characteristics in diabetics, post-stroke and ankylosing spondylitis based on cluster analysis

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INTRODUCTION: A study was conducted to compare the stabilometric parameters of three groups particularly different in terms of postural behaviours, such as 10 subjects with ankylosing spondylitis (AS), 10 subjects with diabetic neuropathy (DN), 10 subjects with post-stroke hemiparesis (PS) and 10 control subjects (CS). The study aims either to investigate whether these type of patients have poorer balance than normal subjects or to determine which of the selected features would be good descriptors of each populations balance impairment.

METHODS: Roemberg test was performed on 40 subjects with 2 Bertec force plates (FP4060-10). We computed 40 measures of the centre of pressure (CoP) divided into temporal, spectral and stochastic classes [1]. K-means cluster statistical analysis was performed in order to evaluate which parameters were able to group together the same type of subjects.

RESULTS: 80% of DN subjects differs significantly from CS relatively to Sway area parameters, Ellipsis 95%, RMS distance [2], the powers contained in [0.25-0.35] Hz and [0.35-0.5] Hz in medio-lateral (ML) direction; in particular in the eyes closed (EC) acquisition for DN group. The diffusion coefficient (Dl) in the DN increased from eyes open (EO) to EC, oppositely to CS. 80% of PS subjects differs significantly from CS in EC condition, relatively to RMS distance, Dl, Hl and Kl [1] stochastic parameters, and in EO condition relatively to the powers contained in [0.75-1.0] Hz in anterior-posterior (AP) direction and frequency 50%. 80% of AS patients differs significantly from CS relatively to sway area, the powers contained in [0.35-0.5] Hz in AP, the powers contained in [0.25-0.35] Hz in ML, Ds [1] in EO condition.

CONCLUSIONS: The presence of balance instability was revealed in DN, PS and AS groups. Analyses of the CoP time-series may lead to a large number of measures. These preliminary results may allow us to suggest guidelines for the choice of appropriate CoP measures for each of these pathologies.

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P.173

Comparison of different video gait analysis rating scales to analyse improvement in gait function after locomotion therapy

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INTRODUCTION: To assess improvements in gait function of CP children after specific therapies different assessments are used in the clinical setting (spasticity, force, range of motion, functional tests). In many cases, video pictures from walking tests are taken, too. However, in most cases they are not analysed any further due to time constraints. The goal of this study was to compare different video analysis scores regarding applicability in a clinical setting and regarding sensibility to document changes in gait function.

METHODS: Seven children with neurological diseases aged 5-15 years were tested before and after a locomotion training period of four weeks. Timed walking tests (10m walking test, 6min walking test) were performed and videotaped in the sagittal and the frontal plane. In addition dimensions standing and walking of the Gross Motor Function Measurement (GMFM) were assessed. Videos were analysed using Dartfish software to get the necessary values to score gait function with the Edinburgh Visual Gait Score (EVGS) [1], a 2d version of the Gillette Gait Index (GGI) [2] as well as an adapted form of the Quality Score (QS) [3]. In addition, the Symmetry Angle [4] was calculated and a subjective evaluation by a PT was performed. Normal data for the GGI was assessed from similar measurements in 15 healthy children.

RESULTS: Four patients improved in more than half of the scores. However, no correlation between the different video scores could be found. Also, the legs did not always develop in the same direction in the different scores. In addition, the scores did only partially match the subjective evaluation and the functional measurements.

CONCLUSIONS: Data show that scoring of gait quality is not easy to accomplish, although it would be of great interest beneath the functional aspects. However, none of the scores used in this study seemed conclusive enough for a further use in the clinical setting; all have their pros and cons. In addition, functional improvement in gait speed leading to changes in gait kinematics may be reflected in deteriorations in the video scores used in this study. Therefore, other aspects of gait quality (e.g. movement variability) should be looked at as well as adapted versions of the scores used.

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Criteria for gait asymmetry in patients with hip osteoarthritis

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INTRODUCTION: Gait in hip osteoarthritis patients is often characterized by asymmetry, but there is no agreement on how to classify gait asymmetry. Significant asymmetry between limbs or groups or an arbitrary cut-off value has been used as criteria for gait asymmetry. The purpose of this study was to propose criteria for gait asymmetry that are feasible and valid for use in the clinic as well as in research.

a) b) c)

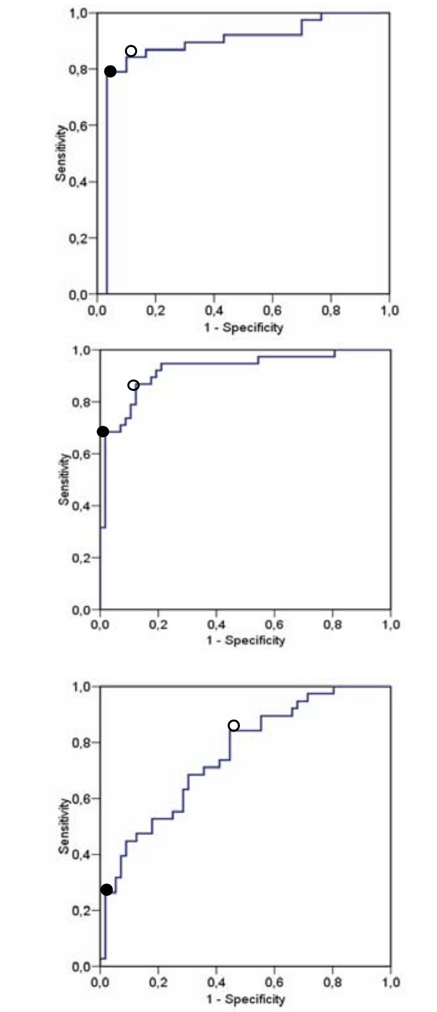

Fig. 1a-c. Discrimination of subjects from the hip replacement group and the comparison group by ROC analysis (○) and by using 10% asymmetry as cut-off value (●) in respectively anteroposterior and vertical trunk movement asymmetry and step length asymmetry.

METHODS: Asymmetry was assessed in 38 subjects scheduled for total hip replacement (age 63±10 years) and 57 subjects in a comparison group without known gait asymmetries (age 77±5 years). Subjects walked six times at steady state along a 7-meter electronic walkway at slow, preferred and fast speed. Between-step trunk movement asymmetry was calculated by an autocorrelation procedure from triaxial accelerometry data obtained from sensors over the lower back. Asymmetry in single support (% of stride time) and step length were obtained from electronical walkway data. All data were normalized for gait velocity.

RESULTS: We found significant differences in gait asymmetry in the subjects with hip osteoarthritis compared to the comparison group for all gait asymmetry parameters (p<.001). Between limb differences in footfall parameters were highly significant in the group of subjects with hip osteoarthritis as well as in the comparison group (p<.001). A 10% cut-off value classified from 67 to 87 % of the subjects to correct group, while parameter specific optimal cut-off values varying from 2 to 7 % for each gait asymmetry parameter determined by receiver operator curve (ROC) analysis, classified from 67 to 89 % of the subjects to correct group.

CONCLUSIONS: A predetermined cut-off value of 10% asymmetry is feasible for use in clinic and research and may be used for individual patients as well as for groups. This criterion has an acceptable ability to classify subjects correctly and is unaffected by the number of subjects included. Significance testing of asymmetry will be affected by sample size, regardless of actual differences in gait asymmetry, and should not be used to determine discriminative ability of a measure.

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Posturography measures for healthy young adults during quiet sitting in comparison with quiet standing

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INTRODUCTION: Measures of postural steadiness – known as posturography – are commonly used for balance assessment during quiet standing [1-3]. Although sitting balance may be characterized via posturography as well, this has not been done to date. As such, the purpose of this study was to characterize the posturography during quiet sitting in comparison to quiet stance and to provide a benchmark for future studies investigating specific control contributions and differences during those two tasks.

METHODS: Twelve young and healthy people were asked to quietly sit and quietly stand on a force platform with their eyes open and closed. For each of the four conditions (two tasks, two eye conditions), one trial of two minutes was executed [4] and the anterior-posterior (AP) and medial-lateral (ML) fluctuation of the body's centre of pressure (COP) calculated (Fig. 1). To quantify and compare the subjects' postural steadiness during sitting and standing, three time-domain, two frequency-domain, and two stabilogram diffusion function (SDF) measures as applied by Maurer and Peterka [3] were identified for both the AP and ML directions. Various statistical analyses were finally used to determine potential differences and correlations between the measures of the two tasks and eye conditions.

RESULTS: The posturography results consistently showed that, for quiet sitting, the time-domain and SDF measures were smaller and the frequency-domain measures larger than for quiet standing (both eye conditions). In addition, the mean COP velocity (eyes open) represented the only measure that was correlated between the two tasks for both AP and ML directions (Fig. 2). Finally, none of the measures during quiet sitting showed significant differences between the two eye conditions, whereas the eye condition affected all time-domain and some of the other measures during quiet standing.

CONCLUSIONS: The observed differences in the posturography measures for quiet sitting and standing can be partially explained by the biomechanical and dynamic differences of the body portions that are in motion during the two tasks (size and inertia). The fact that solely the mean COP velocity for the eyes open condition was correlated between quiet sitting and standing suggests, however, that also the balance control strategies may not be identical during the two tasks. Moreover, the results reveal that quiet sitting is not sensitive to eye condition, implying a more secondary role of the visual modality in comparison to quiet standing.

ACKNOWLEDGEMENTS: The Canadian Institutes of Health Research (#HSF-86427).

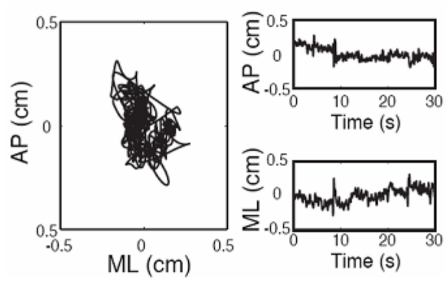

Fig.1 Example of COP fluctuation

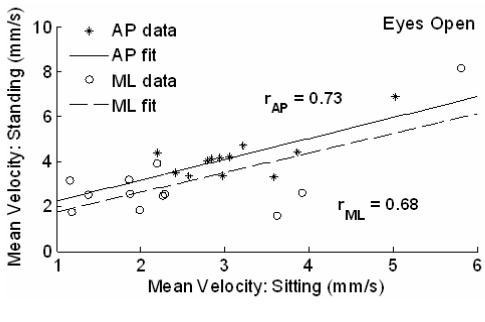

Fig. 2 Correlation between mean velocities

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Force plate targeting alters the variability of temporal and spatial gait measures.

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INTRODUCTION: Whether or not targeting of force plates during gait analysis alters the gait pattern, is still a matter of controversy. Research to date has found that targeting has no effect on: walking velocity; or the variability, timing and magnitude of the ground reaction forces under the foot [1-3]. Whether targeting has an effect on other gait variables such as stride, step, single support time, and the variability of these measures remains to be determined.

METHODS: Ten healthy young adults (mean age = 22.2 years; 6 male) were asked to walk across a walkway with three embedded, hidden force plates, oriented to collect ground reaction force data for 3 consecutive steps (right-left-right steps). Two conditions were presented: a nontargeting condition where all force plates were hidden, and a targeting condition in which participants were instructed to step into a tape outline of the final force plate with their final right step. It should be noted that the force plates themselves remained hidden at all times. Kinematic data were collected with a 7-camera VICON system. A starting location was determined for each participant, and adjusted to ensure that a minimum of ten clean trials, in which full foot contact was made for each force plate, were obtained for each condition.

RESULTS: Preliminary summary statistics revealed that the mean intra-subject percent difference between conditions increased for several of the variability measures; absolute spatial and temporal measures were not affected by condition. Substantial increases in variability of the following measures were observed in the targeting condition: right single support time for the step onto the initial plate (21%), left step time (41), right step length (31%), right step time (20%), and both right stride time (41%) and length (20%).

CONCLUSION: Visual targeting may in fact lead to subtle changes in the motor control of gait, leading to unwanted affects if the goal of gait analysis is for clinical analysis or rehabilitation [4]. These changes may not appear in the ground reaction profile, but may manifest in the variability of gait cycle events. Future research will explore the affect of these differences in variability of other kinematic and kinetic measures.

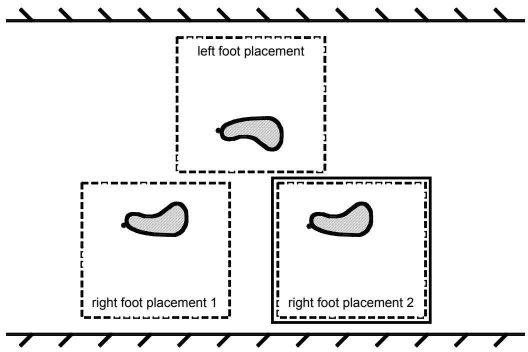

Fig.1 force plate orientation (left)

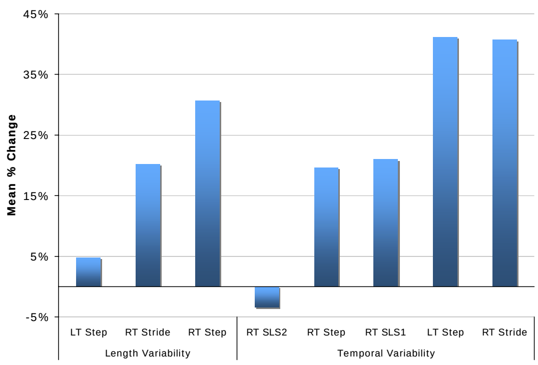

Fig.2 Mean % difference between untargeted and targeted conditions

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Estimating the centre of gravity by double integration in the frequency domain of the horizontal accelerations measured by a 3D force plate: application in standing

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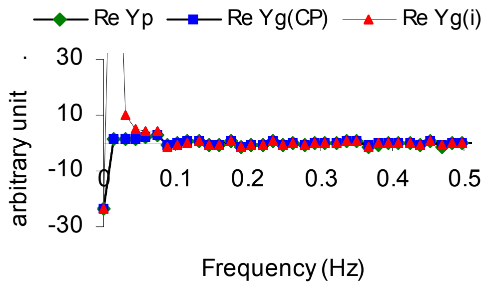
Introduction: In standing, by considering that the body oscillates like an inverted pendulum, the horizontal positions of the body's centre of gravity (CoG) can be used to estimate the body's oscillations. The double integration of the horizontal accelerations does not require any biomechanical model. Unfortunately the Z-to-Z integration point method according to [1] falls short at low frequencies [2] and cannot be used during standing. The aim of the present study is to estimate the CoG positions during standing by computing a double integration in the frequency domain of the horizontal accelerations (DIFDA).

Methods: One healthy male subject (35 years, 1.74 m, 75 kg) was asked to stand as still as possible on a force plate (AMTI, model OR6-WP-1000) during 69 seconds (16-bit A/D converter, 60 Hz). The LPF [3] and Z-to-Z [1] methods were computed. For the DIFDA method, for each axis, a discrete FFT was computed on the acceleration. Real and imaginary part of this FFT were divided by $4\pi^2 f^2$ (f is the frequency). Erroneous values were observed for very low frequencies and were replaced by CoP values (Fig.1). An IFT was computed to get the CoG estimation in the time domain (Fig.2). Due to border effects, 2 seconds of the initial and final recorded data were cut. The average root mean square difference was computed between LPF Z-to-Z and LPF DIFDA methods and expressed as a percentage of the standard deviation of the CoG positions estimated by the LPF method.



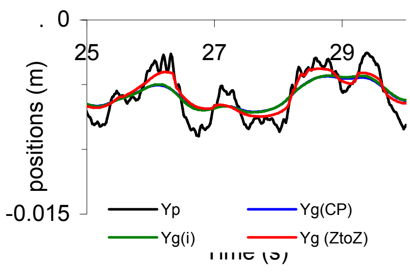


Fig. 1 (upper) Real part in the frequency domain of the CoP (RE Yp), the CoG estimated by LPF method (RE Yg(CP) and the CoG estimated by DIFDA method (Re Yg(i)) along the antero-posterior axis. Fig. 2 (lower) CoP (Yp) and the three CoG positions estimated along the antero-posterior axis. Note the CoG positions estimated by Z-to-Z method are sometimes totally different from the others.

Results: The differences between LPF and Z-to-Z methods were about 15 % whereas the differences between the LPF and DIFDA methods were about 5%.

Conclusions: On the basis of these preliminary results, it seems that the new DIFDA method could be used to evaluate the CoG positions for standing tasks. This method is independent of any biomechanical model. By considering the force plate used, the results tend to confirm that the Z-to-Z method is not suitable for standing tasks.

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P.178

Body sway on force platform: FFT Analysis

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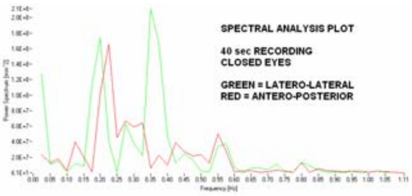
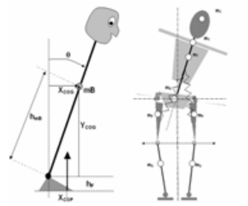
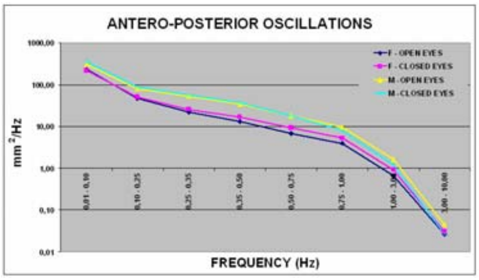
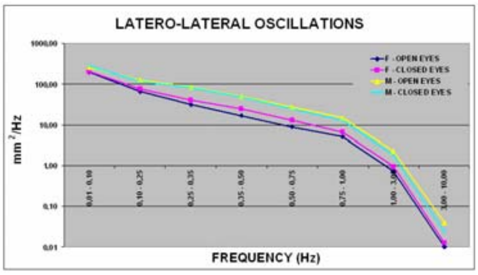
Introduction: Under known assumptions body sway is often described with the Inverse Pendulum theory where the Center of Mass is displaced over the ground by some 2/3 of the subject height. Both Antero-Posterior ane Latero-Lateral Sway, in spite of different mechanical structure, show similar oscillating frequency values. Given the Pendulum Equations for a height range 150-210 cm the corresponding frequency range is 0,041-0,0347 Hz. Higher frequency values observed in clinical experience are suggesting: a “stiffness” model - afference/efference neurologic delays - low frequency muscle responses - feed-forward cortical control.

Methods: By applying the FFT algorythm on a 100 Hz sampled Sway over some 40 seconds recording it has been possible to analyze the Frequency Spectral Composition of both the Antero-Posterior and Latero-Lateral Sway of a population of 1234 subjects (627 F + 607 M) aged 7 to 77 years not showing evident pathological deficit.The minimum detectable frequency (closely related to acquisition time) was 0,025 Hz (1/Acquisition Time). The maximum detectable frequency was 10 Hz (Sampling Frequency /10). ARGO® force platform by RGMD SpA (Genova Italy) was used. Metrologic accuracy of the platform has been demonstrated.Subjects were all showing a SPF score ≤ 9 confirming to be within normality ranges in terms of sway parameters. Harmonic Spectral Power has been calculated over 8 bands on each plane.









RESULTS: Females show, independently from the age group, a significantly lower harmonic power in the range from 0,3 to 1 Hz. 1) Almost no difference has been observed in relation to subject age. 2) Almost no difference has been observed between Open Eyes and Closed Eyes recordings. 3) The similar behaviour in both the Latero-Lateral and the Antero-Posterior plane are rather surprising.

CONCLUSIONS: It seems likely that outstanding values of Harmonic Power in the 0,3-0,7 Hz might reflect a deficit in the capability of damping natural oscillation frequencies. The Harmonic Spectral Analysis parameter seems to be highly significant.

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Step characteristics while walking on drywall stilts: expert vs. novice users

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INTRODUCTION: In the North American construction industry, several tasks must be performed at an elevated height. One method to achieve this elevated height is to wear stilts. Despite the fact that most of tasks done on these stilts are performed while stationary, locomotion remains an essential task that must be accomplished on the stilts. The goal of this study was to compare the spatial-temporal step characteristics while walking on stilts between a group of experienced stilt users and a group of novice stilt users. It is hoped that the differences between these groups may help identify measures that that can be used to asses a worker's competence on stilt use.

METHODS: The subjects in this experiment consisted of a group of 5 expert stilt users, with at least 8 years experience using stilts, and 5 novice stilt users. Participants were asked to perform 4 walking trials with stilts over a 10 m pathway while spatial-temporal step characteristics were measured using the GaitRite system (CIR Systems, Havertown PA). Four level ground walking trials were also collected. Variables analyzed include walking velocity, cadence stride length, step width, stance time and swing time. Variables where analyzed using a two-way ANOVA, with experience level and stilt condition being factors.

RESULTS: The expert group was able to maintain their normal level ground walking velocity while walking on stilts, whereas the novice group showed a significant decrease in walking velocity while ambulating on stilts. The primary cause of the reduced speed of the novice group was a significantly shorter stride length. Walking on stilts also resulted in a significantly longer percentage of time spend in stance and longer double support percentages for the novice group, while the expert group's stance time remained similar to the normal level ground walking condition. The novice group also significantly increased their step width by a significant margin while wearing stilts, while the expert group had a stance width similar to their normal walking.

CONCLUSIONS: While the expert group was able to maintain walking patterns while on stilts that were very close to their normal level ground patterns, while the novice group showed a clear degeneration in walking ability while wearing stilts. The changes in the walking pattern observed by the novice group were consistent with adjustments that have been previously been observed while walking in more challenging situations such as walking on a compliant [1] or slippery [2] surface, and were likely caused by increased anxiety due to the increased postural threat in the stilt condition. The large difference in walking velocity between groups may indicate that this measure may be suitable for assessing an individuals walking competence on stilts.

ACKNOWLEDGEMENTS: Assistance in data collection and analysis from Kaitlin Gallagher and Lindy Buzikievich is acknowledged. Funding for this research was provided by the International Union of Painters and Allied Trades, the United Brotherhood of Carpenters and Joiners of America and the Interior Systems Contractors Association.

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Muscle activation patterns during ground and stilt walking

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INTRODUCTION: Construction stilts have been used for decades to aid workers performing tasks in elevated areas. Stilt use has the potential to modify the muscular activation need to walk. While the perceived risks have previously been studied [1], the muscular activity patterns have not been fully quantified during stilt gait. This study was undertaken to better understand the muscular demands and patterns of muscle activation of the major lower limb muscles during stilt walking at various heights.

METHODS: Ten male subjects were instructed to walk across a 6 metre walkway during four conditions: ground walking, and stilt walking at 1.5, 2.0, and 2.5 feet in height. The moment of inertia (I) about the knee was calculated for the ground, and the stilt height conditions. Participants completed 10 trials per condition. Electromyographic signals (EMG) were collected from tibialis anterior (TA), medial head of the gastrocnemius (GAS), rectus femoris (RF), biceps femoris (BF), the right and left rectus abdominis (RA), and the right and left erector spinae (ES). Lower limb kinematic data were collected to determine the phases of the gait cycle.

RESULTS: With increasing stilt height, peak and average EMG for the TA muscle increases, while the GAS muscle activation decreases. The RF activation peaks increased with an extra activation burst being observed at 40% of the gait cycle, which varied directionally with stilt height. The BF activity was prolonged until toe-off, at which point it dropped to the same level as the ground walking trials. The BF activation peak during heel contact was elevated during the stilt trials with respect to ground walking. The RA and ES muscles showed little change in activation amplitude and timing throughout the gait cycle and were contained within one standard deviation of the ground walking trials.

CONCLUSIONS: During the stilt walking trials the participants learned to walk with a diminished propulsive force provided by the plantar flexors during the gait cycle, likely due to the constraint that the stilt places on ankle range of motion. The increased activation levels of the TA could have been due to vestigial patterning from the central nervous system, although it also contributed to the co-contraction at the ankle that maybe needed for various ankle functions. An increase in co-contraction in TA, GAS, RF, and BF may have been due to the added anxiety that was created due to the increased height of the stilts [2]. The increase in peak TA activity may perhaps be an attempt to prevent foot slap due to an ingrained walking pattern but could also be an attempt to better regulate the COM motion by decreasing the knee flexion that is occurring just after heel contact. The RF muscle was shown to have an extra muscle activation burst as an attempt by the participants to make up the forward propulsion that is lost from the GAS. The I about the knee was shown to increase substantially with stilt height (2.13, 3.27, and 4.57 times the I of the ground walking trials, respectively). It appeared to be a significant contributor to the increase in muscle activation of the RF and BF. With increasing stilt height, BF remained active for longer and had a larger peak amplitude. Activation of thigh musculature during most of the swing phase was reduced to a similar level as ground walking, as the added inertial effects of the stilts facilitated the extensor action of the knee. Those individuals utilizing stilts must be aware that the propulsion typically provided by the ankle muscles would be impaired and require added activity of the hip muscles. Additionally, the added weight and angular resistance introduced by stilts of different heights requires specific modifications in muscle activity patterns needed to walk.

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Changes in sitting posture affects regional chest wall shape and motion during breathing

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INTRODUCTION: Chest wall movement and pulmonary function are affected by gross changes in body position (supine vs standing) [1] and severe postural deformity such as scoliosis [2]. However, little is known about the impact of more subtle changes in posture. Thus, our aim was to determine the effects of changes in sitting posture on ribcage and abdominal shape and motion during breathing..

METHODS: Three-dimensional (3D) chest wall motion was recorded with an electromagnetic tracking device. Sensors on the upper and lower ribcage, spine, and abdomen measured spinal alignment and chest wall motion. Subjects breathed through a mouthpiece and flow was measured with a pneumotachometer. Subjects adopted seven sitting postures: habitual, neutral (reference), slump, thoracolumbar extension, half trunk rotation, full trunk rotation, and lateral ribcage shift. In each position subjects breathed increased dead-space, inducing an involuntary increase in tidal volume to 1.5 times their resting tidal volume (calculated from integration of flow). This was necessary so that volume was matched to compare effects of posture independent of volume changes. Times of end-inspiration and expiration were identified from the volume data. Chest wall and abdomen diameters were determined from sensor displacement in three planes. Diameters at end expiration and the change in diameters from end expiration to end inspiration were calculated. Spinal angles in the sagittal and transverse plane were calculated. Repeated-measures ANOVAs were used to compare differences in spinal angles between postures, differences in chest wall diameters, and displacement between postures.

RESULTS: Subjects attained the target postures, evidenced by differences in thoracic, thoracolumbar, and lumbar spine angles between postures in the sagittal plane and the transverse plane angles ($p<0.0003$). Chest wall diameters and motion differed between postures. In thoracolumbar extension upper ribcage anteroposterior (AP) and lateral diameter at the axilla increased, but lower lateral diameter decreased compared to all other postures ($p<0.0004$). Breathing movement in the lower lateral diameter increased compared to all other postures except for habitual posture ($p<0.008$). In slump posture upper ribcage diameter was smaller, but lower lateral and abdominal AP diameter, and upper AP breathing movement were greater compared to the reference posture ($p<0.006$). In full rotation AP diameters increased compared to the reference posture ($p<0.04$) and in mid- and full rotation there was decreased lateral movement in the upper ribcage during breathing ($p<0.04$).

CONCLUSIONS: This study is the first to show that even subtle changes in postural alignment in both the sagittal and transverse planes affect ribcage and abdominal dimensions and chest wall motion, independent of changes in volume. Further studies are required to determine whether the underlying mechanisms are mechanical (changes in relative compliance) or muscular (due to altered length-tension or competing demands between postural and respiratory functions), and to determine if these changes impact distribution of ventilation.

ACKNOWLEDGEMENTS: Linda-Joy Lee is supported by the Canadian Institutes of Health Research (CIHR). Paul Hodges is supported by the National Health and Medical Research Council of Australia.

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How Accurately People Can Discriminate the Differences of Floor Materials with Various Elasticities

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INTRODUCTION: Special objects called “tactile ground surface indicators” (hereafter referred to as “indicators”) installed on sidewalks help visually impaired people to walk safely (Fig. 1 left). Indicators have been installed on sidewalks in many countries (Fig. 1 right), and the International Organization of Standardization (ISO) is now reviewing these indicators in order to develop a new international standard [1]. However, these indicators sometimes cause the non-visually impaired to trip or stumble. Thus, these indicators also have to be made safer and less of a problem for those who do not use them. There are several facilities in Japan that have installed floor materials of different elasticity to indicate paths for the visually impaired. However, the effectiveness of this method has not been tested. Therefore, this study examined how accurately people can discriminate differences in the elasticity of flooring samples.

METHODS: Flooring samples of different elasticity were presented by placing two walking boards made of plywood, each surfaced with one of 3 different flooring samples, in an end-to-end fashion. Ten young adults whose sight was temporarily cut off by eye masks were asked to walk on the path for 144 trials and indicate whether the flooring samples were different or not.

RESULTS: The percentages of correct answers were high for most pairs of samples (Fig. 2). Moreover, there was a strong positive correlation between the percentage of correct answers and the magnitude of difference in floor elasticity.

CONCLUSIONS: These results indicate that people can distinguish changes of flooring samples fairly accurately, even when there are no convexities, if there is sufficient difference in elasticity between the flooring samples.

Fig. 1 Tactile Ground Surface Indicators installed in Japan (top), and Italy (bottom)

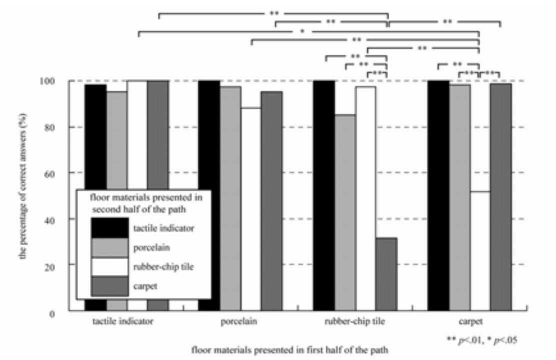

Fig. 2 The percentage of correct answers among the flooring samples

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Adulthood development of postural control: the role of sensory information and martial arts expertise

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INTRODUCTION: Upright stance involves the integration of visual, somatosensory, and vestibular inputs [1,2]. Processing of related sensory information undergoes age-related decline in adulthood, especially in challenging situations where visual cues or diminished (e.g., dim lighting) or where the surface is compliant (e.g., beach). Balance-related sports like martial arts require excellent postural control and there is evidence that young adults engaged in such sports show better postural stability than age-matched controls [3]. However, it remains unclear whether martial arts experts' superior postural performance is related to the availability of sensory information and whether it represents a general motor advantage, an innate ability or an acquired skill. Furthermore, studies examining the role of real-life balance expertise in later adulthood are limited to short-term interventions or studies using sedentary control groups.

METHODS: 40 young (18-30) and 40 elderly (55+) male adults participated in the study; half of them were high-level (black-belts) martial arts practitioners, the other half were engaged in other, non-balance-related sports. Experimental tasks comprised expertise-related postural control tasks and non-expertise-related ('transfer') tasks. Postural control tasks required participants to stand as stable as possible on a platform while visual and/or somatosensory information was compromised. Non-expertise-related tasks comprised a series of motor (walking speed, maximal tapping rate, simple reaction time, finger force control) and cognitive (working memory, processing speed) tasks. We also collected background information regarding training intensity in martial arts practitioners.

RESULTS: There were no age- or expertise-related differences with respect to walking speed and reaction time. Elderly adults had lower maximal tapping rate, lower working memory capacity and slower processing abilities than young adults. However, these age-related changes were similar in martial arts experts and controls, suggesting that martial arts experts are 'normal' with respect to general motor and cognitive abilities. In the expertise-related postural control tasks, our manipulations of visual and somatosensory information availability yielded the intended effects: postural sway increased when visual or somatosensory information was compromised – an increase that was pronounced when both modalities were concurrently manipulated – and this was true for all four age- and expert-groups. However, compared to young adults, elderly showed a larger increase in postural sway when visual or somatosensory information was compromised and this effect was pronounced when both modalities were concurrently manipulated. Compared to age-matched controls, young martial arts practitioners were better in stable standing when somatosensory information was compromised; however this expertise-related advantage was not present in the elderly expert-group.

CONCLUSIONS: Results suggest that young martial arts experts have a specific advantage in postural control that cannot be attributed to a general motor or cognitive advantage. However, so far there is no evidence that martial arts expertise moderates age-related decline in postural control in later adulthood.

ACKNOWLEDGEMENTS: The project was funded by an Onderzoeksfonds KU Leuven Grant (OT 05/25) to Ralf Th. Krampe

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P.184

Postural control of firefighters in eyes open and closed condition after maximal exercise test

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INTRODUCTION: Unpredictable and rapidly changing work conditions, and high physical strain require an alert postural control system among firefighters. Furthermore, fire and rescue situations usually occur in heavily smoky or dark environments. According to Nagy et al [1] firefighters are more dependent on vision for postural control than athletes (ironmen), and postural control of ironmen increased after strenuous exercise only in eyes closed condition. The purpose of this study was to investigate the effects of exercise, eye closure and the level of physical activity on postural control among firefighters.

METHODS: The voluntary subjects were 23 healthy professional male firefighters with an average age of 34 (26-44), height of 181 (172–196) cm, weight of 85 (69–102) kg and BMI of 26 (21–32). The test protocol included a series of postural sway tests and a functional balance test before and after the maximal exercise test, measured on a treadmill**.** Functional balance was measured during walking on a wooden plank. The frequency of physical exercise (1. not at all 2. occasionally 3 1-2 times/week 4. 3-4 times/week 5. >4 times/week). of the subjects was elicited through a questionnaire. We used means ± SD for describing the data, and linear mixed models to study the effect of exercise, eye closure and physical activity on the results of postural control.

RESULTS: Exercise and eye closure significantly (F=9.43-26.5, p<0.001 exercise, F=17.6-21, p<0.001 eyes closure) increased postural sway (table 1) whereas exercise had no influence on functional balance. The influence of exercise on postural sway was significantly stronger (F=3.20-16.7, p<0.05) during tests with eyes open than in the eyes closed condition. Mediolateral velocity of physically active subjects (exercise > 4/week) was significantly (F=5.30, p<0.05) slower compared with less active subjects, but this did not reduce postural sway after the exercise test or in the eyes closed condition.

CONCLUSIONS: Exercise and eye closure increased postural sway. However, the influence of exercise on sway was stronger in the eyes open condition. Maintaining standing position is more typically difficult situations where many balance-demanding conditions occur simultaneously [2]. In this study, eye closure increased postural sway to such an extent that exercise did not significantly increase sway without visual feedback. We recommend further study on postural control of firefighters in smoky and dark environments, in which visual feedback is poor, but not absent.

Variable	**Before exercise**	**After exercise**
Mediolateral velocity (mm/s) **eo**	3.0 ± 0.9	3.9 ± 1.3
ec	4.0 ± 1.6	4.5 ± 1.9
Anteroposterior velocity (mm/s) **eo**	5.1 ± 1.5	7.1 ± 1.5
ec	9.2 ± 3.0	9.5 ± 2.6
Velocity moment (mm^2/s) **eo**	7.3 ± 3.0	10.8 ± 6.1
ec	12.1 ± 6.1	14.1 ± 9.5
Functional balance (s+errors)	9.7 ± 2.1	9.5 ± 2.3

Table 1. Postural control before and after maximal exercise test, eo=eyes open, ec=eyes closed, 1 error=1 s (n=23)

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Energetics of movement: a whole body application of an energetic muscle model in unilateral leg press using a hybrid dynamic approach

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INTRODUCTION: The relationship between mechanical work and metabolic energy cost during movement is not yet clear. Many studies demonstrated the utility of forward dynamic musculoskeletal models combined with experimental data to address such question [1]. The aim of this study was to evaluate the applicability of a muscle energy expenditure model [2] at whole body level, using an hybrid dynamics approach [3].

METHODS: Four participants [28.5±6.0y, 1.8±0.1m, 76.4±4.1Kg] performed a 5 minute squat exercise on unilateral leg press at two different frequencies (25, 40 mpm) and two different load levels (5, 15Kg). Data collected were kinematics (Optotrak), EMG (TMSi), forces and moments under the foot (Amti) and gas exchange data (Cosmed). EMG was rectified, filtered and normalized to MVC [4]. Net joint flexion/extension moments were obtained through inverse dynamics. This same task was simulated using a musculoskeletal model, which took EMG and kinematics as inputs and gave muscle forces and muscle energetics as outputs. Model parameters were taken from literature [5], but maximal isometric muscle force was optimized in order to match predicted joint moments with measured ones [3]. Whole body energy consumption was calculated by summing the energy expended by each muscle. Energy rates predicted by the model were compared with energy consumption measured by the gas exchange data.

RESULTS: Results after partial optimization of maximal muscle isometric forces are shown in Figure 1 and 2. Model results on metabolic energy consumption were close to the values obtained through indirect calorimetry. However, at the higher frequency level, the model underestimated measured energy consumption.

CONCLUSIONS: Preliminary results obtained in comparing model predictions with experimental data are promising. The underestimation of energy consumption at higher frequency can be explained with an increase in energy consumption of the non muscular mass with movement velocity [6]. More research is clearly needed to evaluate this way of computing mechanical and metabolic work.

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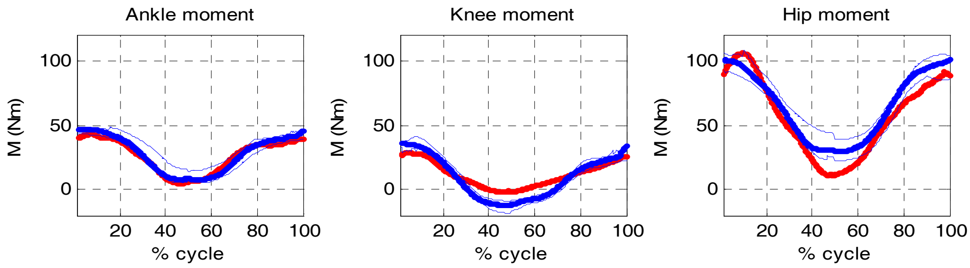

Fig. 1 Joint flexion/extension moments estimated by the model (red lines), and by inverse dynamics (blue lines, median cycle, min and max) for a single test

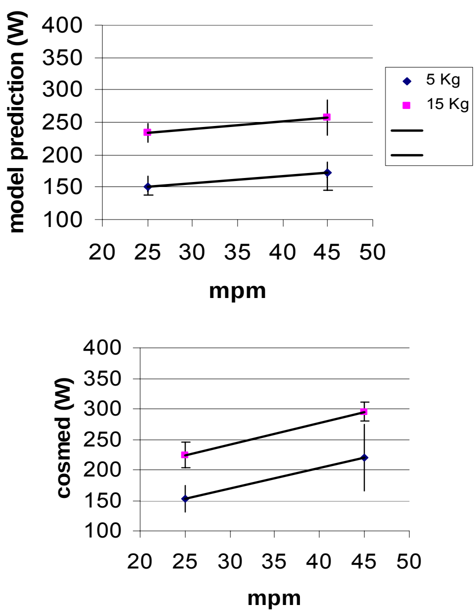

Fig. 2 Mean and standard deviation of total muscular mass energy consumption a) predicted by the model, and b) measured with indirect calorimetry

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Whole-body adaptations to repetitive motion-induced arm fatigue in persons with chronic neck/shoulder pain

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INTRODUCTION: Repetitive upper limb movements are common in everyday life and many occupational settings (e.g. services, manufacturing). Recent works suggests that repetitive motion-induced fatigue causes complex, whole-body reorganization in healthy subjects [1,2]. These adaptations, expressed as changes in whole-body center of mass (COM) and center of pressure (COP) displacements, appear limited in individuals with chronic neck/shoulder pain, potentially affecting their performance capacity. To further delineate these mechanisms, we assessed the effects of repetitive arm movements on shoulder function and movement strategies in individuals with neck-shoulder pain.

METHODS: Fifteen subjects with neck/shoulder pain (intensity ≥ 3/10, duration ≥ 3 months in previous year) and fifteen age/sex matched controls were asked to reach with the affected arm between two targets placed at 30% and 100% of arm length at shoulder height. The task was performed continuously at a speed of 1 reach/second until scoring 8 or greater on either the Borg CR-10 scale [3] or an 11-point numerical rating scale (NRS) for pain. During the task, heart rate (Polar©) was recorded continuously while whole body kinematics (VICON-Peak©) and forces under the feet (AMTI©) were recorded at the end of every minute. Shoulder range of motion (ROM) (flexion and abduction) and cumulative power output (PO) over a 10s dynamic pushing/pulling task (BTE©) were assessed pre- and post-reaching task. Each parameter was analyzed using a two-way ANOVA with repeated measures (group x time), with Tukey's post-hoc comparisons where appropriate ($p < 0.05$). Independent t-tests were used to compare the duration of the reaching task between groups.

RESULTS: Average time to task termination was significantly shorter for the pain group (243±145 sec) than the control group (447±179 sec). A significant main time effect indicated that PO decreases from pre-task (40.5±33.8 W) to post-task (34.3±29.2 W). ROM data indicated a significant main group effect for both flexion and abduction whereby the control group demonstrated greater shoulder ROM (216°±29° and 202°±20°, respectively) compared to the pain group (179°±43° and 154°±53°, respectively). During the reaching task, a significant main time effect for both mean heart rate (HR) and medio-lateral COP range indicated that both values increased during the reaching task (6.4 bpm and 5.05 mm, respectively). Post-hoc analyses revealed significantly higher NRS scores in the pain group during the first minute of the task (2.9±2.1 and 0.3±0.6, pain and control groups, respectively) and increases within each group over time in both Borg and NRS scores (6.0 and 6.5 in control group and 4.0 and 4.1 in the pain group, respectively). Additionally, a significant interaction effect revealed that only the control group demonstrated significant increases in both antero-posterior COM and COP range (mean increase 5.8 mm and 11.56 mm, respectively).

CONCLUSIONS: Decreased PO after the reaching task, combined with increases in HR and Borg scores during the task indicate fatigue in both groups. A significant fatigue main effect on medio-lateral COP range indicates that movement adaptations occur in all subjects, despite differences in pain scores. Yet, these adaptations may be limited during forceful tasks or those with fewer degrees of freedom [1,2]. Only the control group demonstrated increased antero-posterior range of COM and COP at the end of the task. So despite similarities in shoulder PO, both groups have unique adaptation strategies. However, time to reaching task termination, and ultimately, the choice of adaptation strategy, were likely limited by the pain group's elevated NRS scores.

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Effect of weight-bearing training on physical function and postural modulation of soleus H-reflex in humans

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INTRODUCTION: The physiological mechanisms underlying the maintenance of upright posture require the production of adequate motor output using sensory information from around the body. Sustained decreases in proprioceptive inputs induced by physical inactivity may diminish function of the central nervous system (CNS) [1]. However, responses of posture control function to increasing proprioceptive inputs have not been fully elucidated. The purpose of the present study was to investigate the effects of additional weight-bearing training on physical function and postural modulation of the soleus H-reflex.

METHODS: Subjects comprised 27 healthy individuals, allocated to either a training group (loading with additional 10% of body weight for 4 h/day for 5 days; n=13) or a control group (n=14). Physical function was evaluated using a functional fitness test (4-item method: standing and sitting; zig-zag walking; hand working; and self-care working) [2]. H-reflex was elicited by suprathreshold stimulus for the tibial nerve in supine and standing positions. Surface electromyography was recorded in the right soleus and tibialis anterior muscles. Peak-to-peak amplitudes were normalized by the corresponding maximal motor response. Change ratio of standing to supine position was used as an index of postural modulation of the spinal reflex [3]. Differences between before and after the training period were calculated and compared between groups using a t-test.

RESULTS: In male subjects, a greater decrease tended to be seen in zig-zag walking time in the training group (n=9; mean (standard deviation), -0.86 s (0.31 s)) than in controls (n=7; mean, -0.54 s (0.31 s)). While this difference was not significant (t(14)=2.04, p=0.06), a medium-sized effect was noted (r=0.48). In female subjects, a significantly greater decrease in self-care working time was seen in the training group (n=4; mean, -1.03 s (0.67 s)) than in controls (n=7; mean, -0.09 s (0.60 s); t(9)=2.42, p=0.04, r=0.63). Changes in H-reflex ratio of the training group tended to be greater than in controls for males, but no significant difference was identified (p=0.12, r=0.40). Likewise, female subjects showed no significant difference (p=0.70, r=0.13).

CONCLUSIONS: Additional weight-bearing training for 5 days induced conventional increases in proprioceptive inputs and improved physical function in females. As training also caused a compensation response to the additional weight, postural modulation of the spinal reflex was not detected. These results indicate that chronic increases in proprioceptive inputs can contribute to improved dynamic posture control via supraspinal mechanisms even in young subjects.

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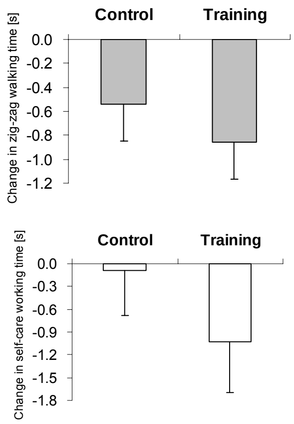

Fig.1 Group mean and standard deviation of pre-post differences in zig-zag walking time in males (top) and self-care working time in females (bottom)

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Stabilometric study of the effect of heel height on postural control

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INTRODUCTION : This study consisted of analyzing the stabilometric tracings of 15 nightclub dancers recorded on a Fusyo stabilometry platform in 4 situations: barefoot and with 3-, 6- or 9-cm high heels with their eyes open.

Statistical analyses of these data showed that wearing heels indeed modified postural control, particularly evident for the variance of speed as a function of the mean position on the Y axis (VYF). This finding means that these dancers do not stabilize their bodies like an inverse rigid pendulum, which has only 1 degree of freedom, but they do so by using at least 2 degrees of freedom: the center of pressure and the ankle. Analysis of variance for each parameter, compared to a fixed factor, heel height, was assessed with multiple comparison Tukey HSD and 2-sided Dunnett tests.

RESULTS: These analyses confirmed that heel height did not significantly modify the mean surface area of the recording in the 4 situations but that it significantly modified at least 1 of the means of the 4 test situations, and equally for the speed standard deviation (SD) (p<0.04%) and VFY (p<0.02). Multiple comparison test results showed that: the mean speed SD distributions in the barefoot vs 6- or 9-cm heels and the mean VFY distribution in the barefoot vs 3-, 6- or 9-cm heels differed significantly. Nashner's research (1977) on human electromyographic responses identified the ankle as the last degree of freedom possible between the body and the ground. Although we know that the center of pressure is located on the sole of the foot, it has also long been known that the center of pressure is not fixed and is very easily displaced. Finally, we recently learned that contractions of muscles in the foot are able to displace the center of pressure (Tortolero et al., 2007).

CONCLUSIONS: When a degree of freedom exists in the ankle, the muscles governing ankle movement are inevitably involved in postural control. However, the activities of these muscles are also inevitably modified by the position of the vertical of gravity compared to the horizontal axis of the ankles: the more this vertical falls in front of the ankle axis, the more the muscles in the posterior compartment of the legs are stretched, and the more this tension mechanically reduces the displacement of the center of gravity, which is defined by VFY. In contrast, when the heels are high, the tension in posterior leg muscles is automatically diminished, which favors the adaptive displacement of the center of pressure. The enhanced speed SD and the VFY even more so demonstrate that the dancers use at least 2 degrees of freedom.

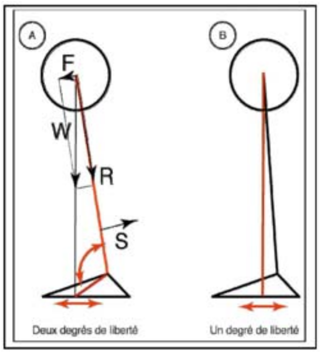

FIG. 4 — Degrés de liberté du pendule humain.

A : Pendule à deux degrés de liberté, un au niveau de la cheville, l'autre au niveau du centre de pression.

B : Pendule à un seul degré de liberté, au niveau du centre de pression.

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Balance assessment in physical education; measurement error in the class room

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INTRODUCTION: Balance, defined in the context of physical education (PE) as the maintenance of equilibrium while stationary or moving, is a skill-related component of physical fitness that relates to movement performance. This component is often part of the content for planned instruction of PE programs that will result in measurable gains for all students; cf. [1]. Appropriate practice that is expected from PE teachers is that they plan assessments that reflect student learning about physical activity as well as its performance [2]. Although functional balance scales are easy to perform and are suitable for daily practical use they often lack enough accuracy. Technology based laboratory systems may give more detailed information about postural balance, however, often exhibit unknown psychometric measurement properties for use in a class room setting [3]. This study aimed to determine indexes of reliability of a balance assessment device in PE students in a class room setting.

METHODS: Thirty PE students (11 male / 19 female; 20.5 ± 1.5 years; 1.73 ± 0.08 m; 64.4 ± 11.9 kg) were recruited for a test-retest study with repeated measurements from the first semester PE classes for Human Movement Sciences and Sport at the ETH Zurich. A MFT-S3 Check balance board was used to assess maintenance of balance on a compliant surface. The best single value out of two trials was taken as the measurement. Indexes of reproducibility included the intraclass correlation coefficient (ICC(2,1)) and the difference against the mean plots of the stability- and the sensor-motor-index (both expressed as a number on a scale ranging from 1 to 9). Differences between individual means were calculated by means of a paired Student's t-test to quantify the systematic error (bias) of the MFT-S3. Level of significance was set at $\alpha \leq 0.05$.

RESULTS: Poor to moderate reproducibility was observed for the stability-index (ICC 0.66; 95% CI 0.39-0.82) and the sensor-motor-index (ICC 0.56; 95% CI 0.56-0.77). Bland-Altman-plots revealed limits of agreement (±1.96 SD) around the mean of 1.7 points for the stability-index (21.25% on the rating scale) and 1.9 points for the sensor-motor-index (23.75%). There were no significant differences between week 1 & 2 for the stability- (p = .26) and sensor-motor-index (p = .22).

CONCLUSIONS: The one measurement protocol showed moderate reliability for group assessments in PE students. It can therefore only be employed with caution in studies of the effect of interventions in PE; e.g. the effects of specific types of balance training in PE students. The value of the test protocol for individualised assessment remains unclear and should be subject to further research. It should, furthermore, be investigated whether an increase in measurement trials will also increase the reliability of the assessment.

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Balance disturbances associated with transitioning to a standing posture

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INTRODUCTION: Postural stability during sit-to-stand and sit-to-walk transitions has been investigated, primarily for the elderly and individuals with Parkinson's disease [1]. However, a variety of additional postures are used during activities of daily living and while at work. Transitioning from these postures to a standing position may challenge multiple sensory systems that are required to integrate information in order to retain postural stability. In addition, maintaining awkward postures may result in muscle fatigue and the propensity toward postural instability, which may give rise to a fall or near fall incident [2]. The purpose of this study was to examine the effects of various static postures, which may challenge different sensory systems, on center of pressure (COP) and time to balance recovery.

METHODS: Thirty male participants aged 18-67 years volunteered for a laboratory study. Participants maintained one of four static postures prior to transitioning into a quiet standing posture. The static postures investigated were bent forward at waist, kneeling on hands and knees, squatting, and kneeling with erect torso. The static postures were held for a duration of 30s, 60s, or 120s. Therefore, the independent variables of interest were static posture and duration within posture. Three replications of each condition were performed for a total of 36 trials. Presentation of the conditions were blocked by replication and completely randomized within block. Phases of the postural transition were identified using a passive motion capture system (Motion Analysis Corporation). Postural sway measures were derived from forceplate data (Kistler). Measures collected immediately following the transition were normalized by subtracting the values obtained during a one-minute quiet standing task. Dependent measures included RMS, range ML, range AP, and velocity of the COP. Time to balance recovery was also calculated (within 3 s.d. of quiet standing velocity).

RESULTS: Postural sway measures following the transition to standing were significantly greater than those of quiet standing. Time to balance recovery was ~5 seconds. Repeated measures ANOVA using mixed models indicated a significant effect of static posture and duration within posture ($p<0.05$) on postural sway measures immediately following the transition to standing and on the time to recover balance. The bent over at waist posture created the largest differences in all COP measures and the longest time to recovery.

CONCLUSIONS: Our results suggest that the posture chosen to perform tasks and duration required to complete the task may affect the individual's balance upon standing. Individuals may be more vulnerable to losing balance upon standing, especially within the first 2-3 seconds. Postures that require adjustment from multiple sensory systems (e.g. visual and vestibular) may lead to higher levels of imbalance upon standing. Alternative postures should be considered, especially when other factors within the environment may increase the risk of falling (e.g. impaired vision or standing on an uneven surface).

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The effect of mechanical and sensorimotor perturbations on the physiological cost of walking

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INTRODUCTION: The aim of the current study is to assess how oxygen consumption and the neural regulation of walking are influenced by immobilizing the ankle joint and vibrating the Achilles' tendon in able-bodied young adults. The rationale for the study was to compare the energetic costs of mechanical and sensorimotor gait perturbations on the physiological cost of walking, including abnormal gait patterns and compensatory strategies employed to maintain stability during gait, which is only possible using a perturbation design in able-bodied individuals. We predicted that introducing gait perturbations would increase gait energetic requirements (i.e. VO2 and amplitude of trunk accelerations), with the combined application of both perturbations eliciting the largest rise in energetic cost.

METHODS: We used a cushioned air cast to minimize the range of motion of the ankle joint and a tendon vibrator to alter ankle proprioceptive feedback to induce mechanical and sensorimotor disturbances, respectively. Eleven able-bodied participants (age:24±4 years; weight: 66±16 kg; height: 162±19 cm) were instructed to walk around a circular track in a gymnasium at their normal, customary walking speed as follows: a) normally; b) with an air cast; c) with continuous Achilles' tendon vibration; and d) with both the air cast and tendon vibration concurrently. Throughout the protocol, oxygen consumption (VO2) was measured using the Cosmed K4b2 unit (Cosmed, Italy) and upper trunk accelerations using the Delsys Myomonitor IV Wireless Transmission and Datalogging System (Delsys, U.S.A.).

RESULTS: Initial analysis of the VO2 results from five individuals, reveals that energy expenditure increases with air cast use and combined air cast and tendon vibration, but not with tendon vibration when applied independently (Fig. 1). Similar trends are detected in vertical accelerations of the upper trunk of all eleven participants, displaying a decrease (2 %) and increase (12 %) in upper trunk accelerations during the independent tendon vibration, and air cast conditions respectively. However, the effect of the combined air cast and tendon vibration was less pronounced and not significant when compared to normal walking. Medio-lateral accelerations of the upper trunk do not yield any statistically significant changes.

CONCLUSIONS: Overall, the effects of the mechanical and sensorimotor gait perturbations in this study are not mutually exclusive or simply additive in their effect on physiological cost, as initially surmised. Through further analysis of the relationship between range of motion and sensorimotor functions during normal gait, improvements to therapeutic interventions for individuals with gait deficits similar to those being invoked (e.g. ankle arthrodesis) may be revealed in the future.

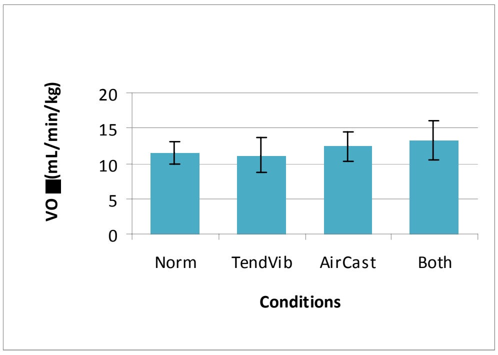

Fig.1 Average oxygen consumption (VO2) during each experimental condition

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New insights into the role of postural sway

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INTRODUCTION: Postural sway is thought to arise from continuous perturbations of the centre of mass (COM) caused by either intrinsic or extrinsic factors. Corresponding changes in centre of pressure (COP) displacement have been explained using passive stiffness, or sensory feedback models in which the COP continually tracks and corrects for ongoing changes in COM position. According to these models, we predicted that an external stabilization of the COM during stance should lead to a significant decrease in COP displacement. The current study used a unique method to stabilize the COM during stance, without the participant's knowledge, to examine the corresponding effect on COP and tonic muscle activity.

METHODS: Nineteen subjects (12 females; 19-28 yrs) were firmly braced with their back against a rigid board to prevent movement at any joint except the ankle. The board was attached to a closed-loop pulley system that allowed normal postural sway at the ankle joint. A brake allowed the experimenter to discretely lock the board (and thus COM) in place in the sagittal plane. In each trial, participants stood as still as possible on a forceplate for 60s. The first 30s stabilized sway and the following 30s was used to calculate the mean COP position to be used as the threshold for "locking." Following the initial 60s, participants stood freely in the "unlocked" condition for 75s and were then locked in place for a further 75s. Trials were performed twice: once with eyes open and once with eyes closed. 3-D kinematics and lower-leg muscle activity were collected. Root-mean square (RMS) and mean power frequency (MPF) of COP displacement (bias removed), angle and position data were calculated for the last 60s of each locked and unlocked condition. RMS of EMG was calculated from triceps surae (TS) and tibialis anterior (TA). A 2 (lock) x 2 (vision) repeated measures ANOVA was used to analyze all dependent measures in the sagittal plane.

RESULTS: In the locked condition, linear displacement of the body was significantly reduced from 1.455 to 0.052 mm, effectively eliminating COM displacement. There was a strong trend for an increase (% change=32%) in RMS of COP ($p=0.09$) in the locked compared to unlocked condition, independent of vision. In addition, MPF of COP was significantly decreased (-53%, $p=0.001$) in locked compared to unlocked conditions. No changes in EMG activity were observed in TS or TA muscles.

CONCLUSIONS: Our results did not support the hypothesis that when COM movement was minimized, COP motion would be significantly reduced. In contrast, COP RMS increased when COM movement was externally stabilized. This provides support for a feedforward component of postural sway, where the COP is used to explore the environment [1], and ensure that the CNS receives a continual flow of reliable sensory information regarding the body's position and orientation.

ACKNOWLEDGEMENTS: Supported by NSERC

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Feedback during COM stabilization does not prevent exploratory COP behaviour during upright stance

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INTRODUCTION: We have recently shown that when the centre of mass (COM) was externally stabilized during stance, COP displacement increased. This finding suggests that the COP is used to explore the environment [1] and ensure the CNS receives constant flow of reliable sensory information. The question remains whether similar exploratory behaviour of the COP would be observed when visual confirmation of COM stabilization was available. In the current study, we used a novel paradigm to stabilize COM motion and provided participants with visual feedback of the COM. We hypothesized that when COM movement was eliminated, and visual feedback was provided, increases in COP motion would still be observed.

METHODS: Seven subjects (5 females; 25-35 yrs) were firmly braced with their back against a rigid board to prevent movement at any joints except the ankle. The board was attached to a closed-loop pulley system that allowed normal postural sway at the ankle joint. A brake allowed the experimenter to discretely lock the board (and thus COM) in place in the sagittal plane. In each trial, participants stood as still as possible on a forceplate for 60s. The first 30s stabilized sway and the following 30s was used to calculate the mean COP position to be used as the threshold for "locking." Following the initial 60s, participants stood freely in the "unlocked" condition for 75s and were then "locked" for a further 75s. Trials were performed twice with eyes open: once with no feedback and once with real-time visual feedback of the sagittal plane COM position. Root-mean square (RMS) and mean-power frequency (MPF) of COP displacement (bias removed) were calculated for the last 60s of each locked and unlocked condition. 3-D kinematics and EMG were also collected. A 2 (lock) x 2 (feedback) repeated measures ANOVA was used to analyze all dependent measures in the sagittal plane.

RESULTS: No differences were found in mean COP position across conditions. There was a significant interaction between lock and feedback on RMS of COP ($p=0.013$). Post-hoc tests revealed that the RMS of COP increased in locked compared to unlocked conditions when feedback was available (% change=155%), and increased to a lesser extent during locked compared to unlocked conditions with no feedback (29%). MPF of COP decreased (-42%) when COM was locked, independent of feedback ($p=0.004$) and the MPF of COP was significantly increased (114%) in the feedback compared to no feedback condition ($p=0.003$).

CONCLUSIONS: External stabilization of the COM, even with visual confirmation provided through real-time feedback, did not decrease COP displacements. On the contrary, it led to even greater increases in COP motion with visual feedback compared to no feedback. This finding provides further evidence for the feedforward or exploratory role of postural sway during upright stance.

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Strategy choice in stepping over obstacles, effects of gait velocity and added mass

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INTRODUCTION: In subjects stepping over an obstacle, two strategies have been observed: shortening the planned step to place the foot in front of the obstacle first, or lengthening the step to place the foot over the obstacle directly. It was hypothesized that the choice follows from a minimization of displacement relative to the planned step [1]. According to this criterion, lengthening and shortening strategies are equally probable when the obstacle is positioned in the middle of the planned foot position. However, lengthening appears more frequently used, possible due to the larger dynamic stability margin [2], which might also explain a preference of older adults for the lengthening strategy [3]. The aim of the present study was to further elucidate the importance of stability as a determinant of strategy choice.

METHODS: Eight young healthy adults walked on a treadmill at 3, 4, 5 and 6 km/h, at 4 km/h with and without carrying a 10% body mass backpack. Virtual obstacles, moving toward the subject, were projected onto the treadmill, timed and positioned on the basis of on-line heel contact information [4] to coincide with a planned foot placement. Full-body, 3D kinematic data were collected (Optotrak). Twenty obstacle avoidance trials were performed for each condition. To study gait stability, the angular momentum in the sagittal plane was calculated for normal steps and obstacle avoidance steps. The number of steps for angular momentum to return to normal after avoiding the obstacle was determined. GEE was used for statistical analysis.

RESULTS: Strategy choice was strongly subject-dependent. The probability of a short step increased significantly with gait velocity ($p=0.02$; mean probabilities 25, 27, 44 and 68%) and increased non-significantly with added mass ($p=0.28$, mean probabilities 27 and 51%). The relative increase in forward angular momentum was independent of velocity ($p=0.53$) and higher during the long than the short step strategy ($p=0.001$), while the number of steps used to reduce angular momentum to normal decreased with velocity ($p=0.01$), but was not affected by strategy ($p=0.83$).

Conclusions: The long step strategy causes a larger increase in forward angular momentum, however this increase is more easily compensated after ground contact, such that the number of steps to regain steady-state gait is not different between strategies. If faster walking facilitates regaining stability as the data suggest, this may explain why the short step strategy is more common at higher velocities.

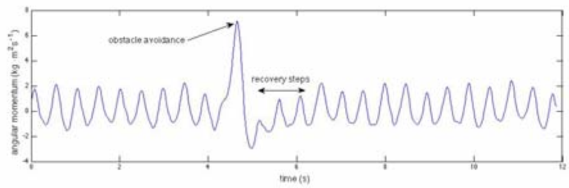

Fig.1 Representative time series of angular momentum

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Identification of motor unit discharge patterns in the gastrocnemii muscles during quiet standing

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Introduction: The recent use of an ultrasound imaging [1] provided new insights into structural changes of calf muscles associated to single body sways, but the neuromuscular strategies underlying these changes remain unknown. In this study we investigated, for the first time, how the electrical activity of both medial (MG) and lateral (LG) gastrocnemii reflects balance control at the level of individual motor units (MUs), by decomposing the surface electromyograms (EMG) into trains of MU action potentials (MUAPs).

Methods: Eight healthy subjects (range: 18 – 36 yr; 55 – 90 m; 1.62 – 1.95 kg) stood comfortably with eyes open for 40s over a KISTLER 9286 AA force-plate (Milan, Italy). Single differential EMG signals were recorded from MG and LG with a matrix of 120 electrodes (LISiN, Politecnico di Torino, Italy) and synchronized with the centre of pressure (CoP). EMG was amplified, band-pass filtered (10–500 Hz) and sampled at 2048 Hz with a 12-bit A/D converter. The instants of MUs activation were estimated by decomposing the EMG with the Convolution Kernel Compensation (CKC) technique [2]. The trajectory of body centre of gravity (CoG) was estimated from CoP [3] and decomposed into forward and backward sways, so that instantaneous discharge rates of identified MUs were separately calculated for individual body sways.

Results: 3 to 11 MUs were identified jointly from MG and LG muscles. The instantaneous discharge rate of identified MUs was statistically different between forward and backward sways (range: 6 – 17.3 and 0 – 10.6 pulses per second (pps); respectively; one-way ANOVA, $p<0.05$; 0 pps means de-recruitment of MUs). Frequently, but not always, MUs were de-recruited during backward sways and re-recruited during forward sways (Figure 1).

Conclusions: The discharge rate and the recruitment of MUs within MG and LG muscles seems to be dynamically modulated throughout quiet standing, with the forward body sways resulting in activation of more MUs and at higher discharge rates than the sways in backward direction. Such periodical modulation likely reflects the impulsive nature of body stabilization during quiet standing [1].

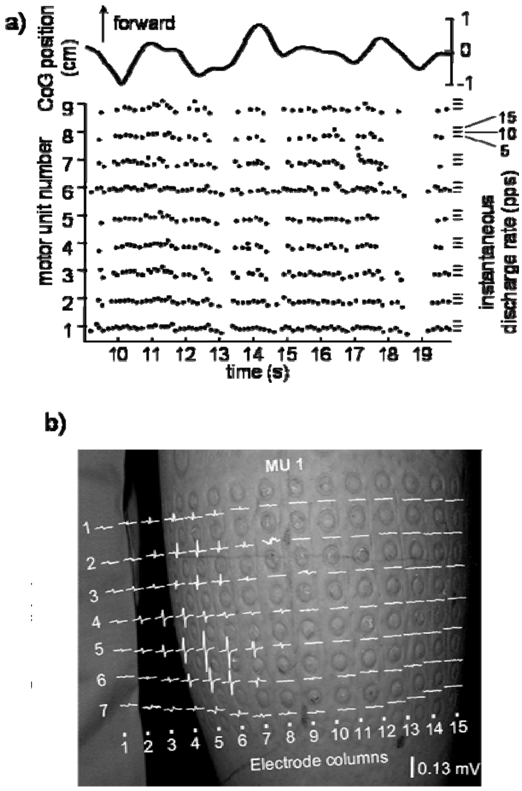

Fig.1 *a)* MU discharges (•) identified from both gastrocnemii during quiet standing (subject 1). Thick line depicts the position of CoG in the sagittal plane. *b)* MUAPs of MU 1 from *panel a)* identified from MG muscle. The prints of the circles on the skin reflect the position of the surface electrodes used for EMG detection

ACKNOWLEDGEMENTS: This work was supported by the Brazilian National Research Council (TV) and by a Marie Curie Intra-European Fellowships within the 6th European Community Framework Programme (Contract No. 023537) (AH).

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Abdominal muscle reactions to rapid shoulder flexion in a situation without upright postural demand

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INTRODUCTION: In standing, voluntary arm movements are associated with activation of trunk muscles, presumably to stabilize the spine and minimize perturbations to the upright trunk posture and standing equilibrium. The activation of the trunk muscles is anticipatory and its onset frequently precedes that of the prime mover muscles of the shoulder. The observation that the deepest abdominal muscle, the transversus abdominis (TrA), often is activated first and, in addition, in a direction independent manner, has been taken as an indication of its role as a spine stabilizer [1]. The purpose of the present experiment was to further understand the role of individual trunk muscles, particularly the TrA, in spinal- and postural control by investigating abdominal muscle coordination in association with rapid shoulder flexion movements performed in a side-lying position, i.e. with minimal postural demand with respect to keeping the trunk upright.

METHODS: At the time of abstract submission, data from 7 healthy male subjects were analyzed. The subjects lay on their right side on a horizontal swivel-table with the pelvis and lower limbs strapped to an immobile part and the trunk to a part movable in the horizontal plane with minimal friction [2]. Via a handle in the subject's left hand, resistance to shoulder movement could be applied through a weight and pulley system. Upon an auditory cue, the subject was to perform a horizontal 90° shoulder flexion with straight arm as fast as possible. Three sets of 6 shoulder movements were performed with 0 kg, 1.25 kg and 2.5 kg resistance. Muscle activity was measured with intramuscular fine wire EMG electrodes placed under guidance of ultrasound bilaterally in TrA, obliquus externus (OE), and rectus abdominis (RA). Surface EMG was recorded from the anterior portion of the left deltoideus (DEL). Onsets of abdominal muscle activation were analyzed in relation to the activation onset of DEL (negative sign = onset before DEL).

RESULTS: On the left side, the onset latencies across resistance levels ranged 25 to 45 ms for TrA, -40 to 15 ms for OE and 113 to 154 ms for RA. On the right side, corresponding onset latency ranges were -5 to -1 ms for TrA, -5 to18 ms for OE and 90 to 111 ms for RA. No consistent trend with increasing resistance levels was observed. A tendency was present towards earlier onset on the right side for TrA.

CONCLUSIONS: All three abdominal muscles investigated showed a bilateral onset of activation in association with a unilateral voluntary arm movement performed in a body position without upright postural demand. Onset latencies for TrA and OE suggested a feed-forward activation mechanism as has been suggested for standing. Absence of an earlier pre-activation of TrA than of the other abdominal muscles, previously seen with corresponding arm movements in standing, might indicate that such an activation pattern is specifically related to the control of the upright posture.

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Reticulospinal control of presynaptic inhibition in primary afferents of the cat

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INTRODUCTION: An efficient way to provide a specific control of the flow of sensory information is to reduce the transmission from some primary afferents before reaching targets within the spinal cord. This can be done by presynaptic inhibition, which is produced by spinal interneurons with GABAergic axo-axonic synapses on primary afferent terminals. During the GABA activation, Cl- anions escape the negative intra-axonal environment and its electrophysiological consequence is a primary afferent depolarization (PAD). PADs can be evoked by stimulation of a variety of inputs, including peripheral (cutaneous, muscle, articular) or supraspinal afferents.

Previous studies showed an overall increased and phase-dependent modulation of PADs evoked by cutaneous or muscle afferent inputs during fictive locomotion, suggesting that the activity of the underlying PAD interneurons are controlled by the central pattern generator (CPG) for locomotion. Studies in anesthetized cats indicate that reticulospinal inputs can modify the amplitude of PADs evoked by sensory inputs [1]. However, the details of the interneuronal networks mediating such interaction are unknown. Thus the aim of this study was to assess the convergence of reticulospinal and sensory inputs on common interneurons mediating PADs using spatial facilitation and modulation during fictive locomotion, scratch and contralateral weight support.

METHODS: All experiments are acute and terminal. Cats are anaesthetized then decerebrated and a laminectomy allows access to spinal lumbar segments for afferent recordings. Selected nerves from hindlimbs are dissected free and stimulated and recorded with bipolar electrodes. Afferent depolarization is recorded in a cut dorsal rootlet as dorsal root potential (DRP) and intra-axonally with micropipettes (PAD) [2]. Single afferents are identified using several electrophysiological criteria. Reticulospinal fibres are stimulated in discrete reticular nuclei or in the medial longitudinal fasciculus. The occurrence of fictive locomotion is spontaneous following decerebration and scratch is evoked by applying d-tubocurarine on C1-2 segments and pinna stimulation. The scratching activity in one hindlimb is always accompanied by tonic extensor activity in the other hindlimb (fictive weight bearing) [3]. Convergence on spinal interneurones is tested with spatial facilitation at rest recorded in individual axons [4]. Modulation of PAD is assessed by comparing the averaged PAD amplitude in the different tasks and in different phases of the rhythmic activities.

RESULTS: Combining reticulospinal and sensory stimulation for evoking PADs in cutaneous (n=3) or muscle (n=18) afferents have shown a complete absence of spatial facilitation. However it was seen when combining two sensory inputs (n=4)[4]. The amplitude of PADs and DRPs evoked by reticulospinal stimulation was phase-dependent during fictive locomotion and always reached maximal amplitude during flexion. The maximal PAD amplitude evoked by cutaneous or muscle afferents occurred in various phases of the fictive step cycle. In many axons, the maximal PAD evoked by reticulospinal and by sensory inputs occurred in opposite phases. Comparison with fictive scratch and weight bearing will be presented.

CONCLUSIONS: Absence of spatial facilitation indicates that there is no convergence on common PAD interneurons. This suggests that there is a private pathway mediating presynaptic inhibition in primary afferents by reticulospinal signals. Different modulation patterns of PADs and DRPs evoked by reticulospinal and sensory inputs showing in the same axon strongly support a separation of presynaptic inhibitory pathways.

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Cortical contribution to the intralimb and interlimb coordination during bipedal locomotion in monkey

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INTRODUCTION: Bipedal (Bp) locomotion is a highly tuned motor behaviour that requires the functional integration of posture and limb movement. The Bp walking Japanese monkey, M. fuscata, is a valuable non-human primate model for advancing understanding of CNS mechanisms that contribute to the control of Bp locomotion [1, 2]. Our previous functional-imaging study by FDG-PET had shown that the foot, leg and trunk regions of primary motor cortex (M1) were significantly activated during BP locomotion in monkey. This result suggested that M1 has its specific functional role for the elaboration and refinement of monkey Bp locomotion. In this study, we have examined in considerable detail the functional role of M1 on the Bp walking and standing ability of monkeys by means of cortical inactivation.

METHODS: Two adult male Japanese monkeys were the subject of this study. These monkeys had acquired the Bp-walking capability smoothly on the surface of a moving treadmill belt. After the cortical mapping by intracortical microstimulation (ICMS) of M1, we focally microinjected muscimol (a $GABA_A$ agonist) into the left side digit, ankle, knee, hip and trunk region, respectively, and observed its effects on the monkey’s Bp locomotion and upright posture. The locomotor tasks included 1) Bp walking on a level (Bp-level), and 2) Bp walking on an obstacle attached level treadmill belt (Bp-obstacle). The obstacle was 5cm height rectangular block and fixed on the right side of walking path. Video recording of locomotor patterns and the upright posture were routinely made using high-speed video system and kinematically analyzed.

RESULTS: ICMS clearly showed foot - leg representation of M1 (digit / ankle regions at most medial and trunk region at the lateral on the convexity) with smaller electrical stimulation. The muscimol injection into medial site (digit / ankle region) resulted in a flexed lower limb joints including hip, however Bp standing monkey could keep upright posture stationary. During Bp-level walking, the major locomotor deficit was the dragging of the right paw (contralateral to the injection site) along the treadmill belt at the initiation of the swing phase. Paw drag was reflected in the increased plantarflexion of the metatarso-phalangeal and ankle joint and the reduced ankle dorsiflexion during that period. The well-organized stance-swing phase coupling pattern was significantly disrupted.

During Bp-obstacle walking, the monkeys always stumbled over the obstacle. After muscimol injection into lateral site, the body axis bent further forward. This was more remarkable in lateral trunk region muscimol injection than in medial injection. However, the rhythmical left and right limb movements were essentially preserved without paw dragging.

CONCLUSIONS: These results indicate that the primary motor cortex in monkey normally controls a significant contribution to the level of intralimb and interlimb coordination through the regulation of the lower locomotor centre such as stepping-related spinal circuits during BP locomotion.

ACKNOWLEDGEMENTS: Supported by Grant-in-Aid for Scientific Research on Priority Areas “Emergence of adaptive motor function through Interaction between body, brain and environment” from Ministry of Education, Culture, Sports, Science and Technology of Japan.

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Proactive strategies for potential loss of ground support during human walking

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INTRODUCTION: Misstep at an unexpected hole during walking leads serious injuries. Previous studies investigated muscle reflex and postural response to an unexpected loss of ground support [1, 2]. If one anticipates potential perturbation during walking, he/she would alter gait pattern [1]. This proactive strategies and very important as well as reactive strategies. In the present study, we compared muscle activities and lower limb kinematics during walking with and without anticipation of potential perturbation.

METHODS: Ten young healthy male subjects participated in this study. Ground reaction forces and surface electromyography (EMG) from the both side of the tibialis anterior (TA), soleus (SOL), medial gastrocnemius (GAS), rectus femoris (RF), biceps femoris (BF), erector spinae (ES) and sternocleidomastoid (SCM) muscles were recorded (1 kHz). Ankle and plantar angles of the right limb were measured by using high speed camera (250 Hz). A drop in the support surface (8.5 cm) could be created by removing the board on the force plate. The support surface was not dropped in the first nine trials (control trial). After the control trials, subjects were instructed that the wooden board might be removed. If the board was removed, participants dropped their right limb (perturbed trials). If the board was not removed, participants walked on the flat surface (catch trials). The perturbed trials were followed by three consecutive normal walking (washout trials). For each subject, 9 control, 12 washout, 8-10 catch and 5 perturbed trials were collected. Ankle and plantar angles at the foot contact and integrated EMG (IEMG) during 100 ms around the foot contact were compared among control, washout and catch conditions.

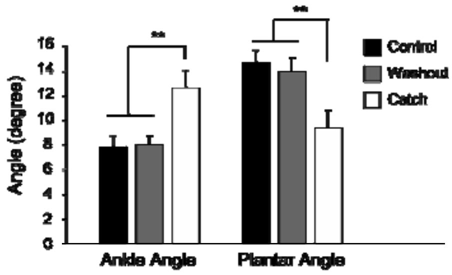

Fig. 1 Angles at foot contact. For the ankle angle, zero indicates the value during normal standing an d positive value means plantar-flexion. For the plantar angle, zero indicates that plantar surface was parallel to the floor. ** $p < 0.01$

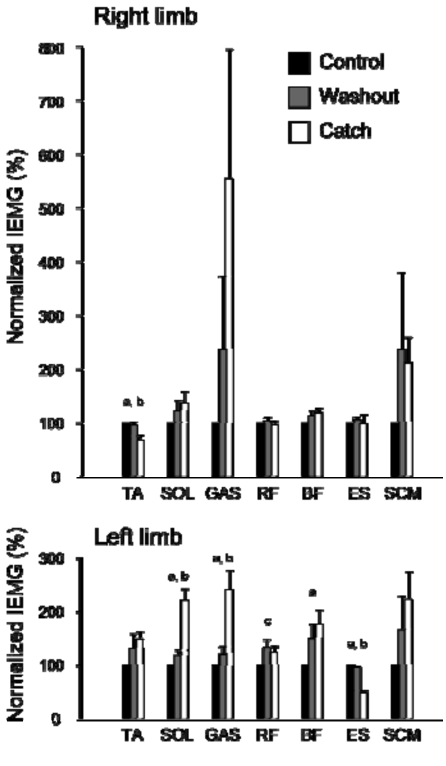

Fig. 2 Muscle activation during right foot contact. Significant difference were shown in alphabet (a, between control and catch; b, washout and catch; c, control and washout)

RESULTS: Ankle was more plantar-flexed and plantar surface was more parallel to the floor in the catch trials compared with the control and washout trials. For the catch trials, the activation of right TA and left ES were smaller and left SOL, GAS were larger than control and washout trials. Left RF was more activated during washout trials than control trials.

CONCLUSIONS: Subjects decreased activation of the right TA and plantar-flexed the right ankle when the support surface might be dropped. This may be in line with the toe-first touchdown which would contribute to absorb the impulse when they dropped. Large muscle activities of the left limb might support the subject's weight. This would be the cautious strategies for the potential loss of the ground support.

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Postural stabilization effects of light finger touch do not come from plane-specific sensory cues of postural orientation

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INTRODUCTION: A light finger touch, while providing no mechanical support, can stabilize posture. Based on the finding of a positive correlation between hand shear force and the center of pressure (CoP), a "bottom-up mechanism" has been proposed that the above touch effect comes from somatosensory information from finger which provides a reference of postural orientation such that postural sway could be corrected [1-2]. A literature review, however, revealed that a typical paradigm in this line was limited to feet positions with a very uneven distribution of inherent postural instability, e.g. heel-to-toe stance with instability mostly in the medio-lateral (ML) plane or normal stance in the anterior-posterior (AP) plane. It was further realized that the correlation between fingertip forces and postural sway- the foundation of the "bottom-up mechanism"- is plane-specifically limited, or mostly distributed, to the plane with greatest instability; and so are the postural stabilization effects. In other words, the operation of the "bottom-up mechanism" depends on availability of plane-specific cues of postural orientation.

METHODS: This study aimed to further examine the mechanism of the touch effect, by using a dual-plane paradigm. The feet-together position was chosen for its inherent instability in both the AP and ML planes. A sway-referenced design manipulated the conditions to contain online information regarding postural sway either in AP and ML planes (stable touch surface), almost only in the ML plane (touch surface with body-referenced AP sway), or nearly in no plane (touch surface with body-referenced AP-ML sway). Postural sway was measured from one-second moving window of root-mean-square, after subtracting the mean, of CoP taken from a dual-forceplate. It was hypothesized that, based on the "bottom-up mechanism", postural sway would increase in the AP plane with body-referenced AP sway and in the ML plane with body-referenced AP-ML sway.

RESULTS: The results showed postural stabilization effects in both planes with body-*r*eferenced AP sway, but no effects in both planes with body-referenced AP-ML sway.

CONCLUSIONS: Postural stabilization effects of light finger touch do not come from plane-specific sensory cues of postural orientation. Another "top-down mechanism" may involve in the touch effect coming from optimizing another supra-postural task.

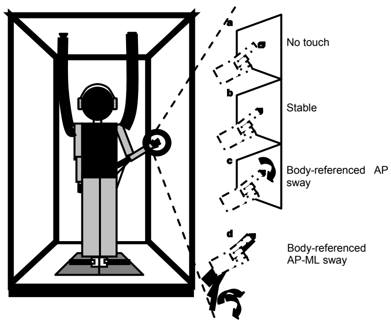

Fig.1 The design of this study showing four conditions

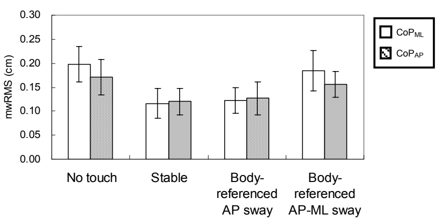

Fig.2 Measures of postural sway of CoP_{ML} and of CoP_{AP} in the four conditions

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The influence of walking speed on trunk sway

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INTRODUCTION: Falls in elderly and others prone to fall often occur during walking. It has been suggested that the elderly prone to fall reduce walking speed in order to decrease body sway and therefore avoid a possible fall. Thus defining the relationship between gait speed and balance measures, such as trunk sway, might provide insights for prevention. The purpose of this study was to investigate the influence of age, gender and walking speed on trunk sway during natural overground walking.

METHODS: Twenty community-dwelling healthy elderly people (mean age 70.0 +/- 5.0 years, 10 male) and twenty gender-matched young adults (mean age 23.2 +/- 3.6 years) participated in this study. Subjects were asked to walk barefoot along a flat, 12.5 m length of the laboratory at five different self-selected speeds; very slow, slow, normal (preferred), fast and very fast in a randomized order. Each velocity was repeated 3 times and data for the middle 7.5 m of each walking trail were analyzed. Balance was measured using a SwayStar™ system with 2 angular velocity transducers (roll and pitch plane) mounted at the level of lumbar spine.

RESULTS: The effect of gait speed on trunk sway was similar for elderly and young. Trunk angular velocities were increased for fast walking and reduced for slow walking compared to normal walking. Fast walking increased trunk roll and pitch angle compared to normal and slow walking, but no differences in trunk angles were seen for slow walking compared to normal walking.

Elderly people had greater trunk sway angles in roll and pitch compared to the young except for very fast walking. Trunk angular velocities in roll were increased in the elderly for all walking speeds, in pitch too except for very fast walking. Young females showed greater trunk roll angles than males for slow and very slow walking. No other gender differences were seen in either trunk pitch angles or in roll and pitch trunk angular velocities.

CONCLUSIONS: Faster walking speeds than preferred leads to an increased trunk sway in the young as well as in the elderly. Elderly people show greater trunk sway than young during walking, except when walking very fast. We assume that increased trunk stiffness in the elderly may lead to larger overall trunk sway. Reducing gait speed will reduce trunk sway velocity but not its amplitude, and therefore only slower than preferred gait speeds lead to lower velocities but no changes in sway angles. In contrast, greater trunk roll in young females during slow walking may be caused by a greater pelvis flexibility in young females.

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Is neural modulation of activity in the muscles across the ankle necessary to maintain balance?

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INTRODUCTION: It is believed that human standing requires neural modulation of the muscles crossing the ankle joint, i.e. soleus (S), gastrocnemius (G) and tibialis anterior (TA). Neural modulation is required because the upright human is passively unstable on account of the relatively low intrinsic ankle stiffness [1-3]. Surprisingly Kelton and Wright reported that upright human configuration can be maintained entirely passively; in fact they found periods of 1 to 5s in which both S and TA were inactive [4]. The same authors implied that the possibility of entirely passive balance depends finely on the position of the Centre of Gravity (CoG) relative to the ankle joint and they also implied the existence of a passively stable zone within which neither plantarflexor or dorsiflexor activity is required. These facts suggest two questions: Is it possible to stand with S, G and TA un-modulated in activity at the same time? While TA is passive, is there a recruitment order for G and S dependent on the sagittal position of the CoG?

METHODS: Seven healthy participants (37±13 years old) performed deliberately exaggerated sagittal sways for 30-40 s each trial with each foot on adjacent force platforms (AMTI). A ten camera motion analysis system (VICON) was used to measure the body kinematics. Both kinematics and force plate data were sampled at 60 Hz. Surface EMG (Delsys) data were recorded from G and TA, amplified (×1000) and band-pass filtered at 20-450 Hz. One ultrasound probe was fixed along the left calf and the other along the left TA. Changes in S, G and TA muscle length were calculated from the ultrasound recordings. For each trial the forward and backward part of the sagittal sway was identified manually from the ankle angle and torque data. For each muscle, the periods of passive or un-modulated behaviour were identified from the EMG and ultrasound records.

RESULTS: During backwards sway, two subjects out of seven clearly showed S, G and TA un-modulated in activity at the same CoG position. This was seen for a small range of CoG positions (max 10 mm) and when the subjects' CoG was close to the ankle joint. For both subjects, S started to be modulated at CoG positions closer to the ankle joint than G. For the first participant S and G started to be modulated when the CoG was 13mm and 50mm in front of the ankle respectively; for the other participant the difference was less strong (S started at 16 mm while G at 25mm of CoG). During forwards sway nobody showed a region in which the three muscles were un-modulated at the same CoG position.

CONCLUSIONS: Standing without modulation of activity in S, G and TA is possible without loosing balance. In our subjects this occurred for a very small range of CoG. Therefore, in normal standing, it would require the person to be finely balanced (very small range of movement at the ankle joint). Furthermore the CoG position needs to be closer to the ankles than most people normally maintain. In fact, experiments confirm that, if the person is very still, his short range ankle stiffness could be greater than the load stiffness [3] and therefore balance in an un-modulated configuration might be possible. G and S do not behave exactly in the same way and, for the subjects showing un-modulation in the muscles, there is a consistent order of recruitment: S is recruited when the CoG less forward from the ankle joint than G.

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Multi-sensory internal representations of visual information for the control of arm movements

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INTRODUCTION: Although a reaching movement could be performed just through the integration of the visual information about the target position and proprioceptive information about the arm configuration, i.e. using an egocentric representation of the movement, there is experimental evidence suggesting that our movements are also controlled in a exocentric reference frame. For instance, our behaviour is affected by our orientation in space. To better understand the role of the different sources of sensory information that contribute to an exocentric representation of the movement, we developed a virtual-reality protocol in which an imperceptible visuo-kinesthetic conflict about the subject orientation could be produced.

METHODS: Forty subjects were asked to align their hand with memorized visual stimuli after a lateral inclination of the head. The amplification or reduction of the visual effects of the head rotation generated a decoupling between the visual and the kinesthetic information about the subject's orientation. Subjects performed the task with three different feedbacks of the hand: kinesthetic (K), visual (V) and visuo-kinesthetic (VK).

RESULTS: In the K condition the subjects' motor behaviour was not affected by the conflict, whereas a slight deviation of the responses was observed in the VK condition. The strongest effect of the conflict occurred in the V condition. However, even in this condition the subjects' responses were never completely coherent with the visual information. Sensory integration of egocentric and exocentric cues depended on feedback about the response.

CONCLUSIONS: These results are consistent with previous models of sensory integration [1-3], which hypothesize that our brain encodes sensory information in several reference frames simultaneously and that interposed recurrent neural networks (RNN) optimize the information and render all internal representations coherent. However, those models cannot predict differing effects of the conflict in the three feedback conditions. This result can be predicted only if the head rotation impairs the functionality of the RNN and, in particular, reduces the ability to reconstruct missing sensory information.

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The speed-accuracy trade-off effects on the gait initiation planning

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INTRODUCTION: Most of the daily human activities,

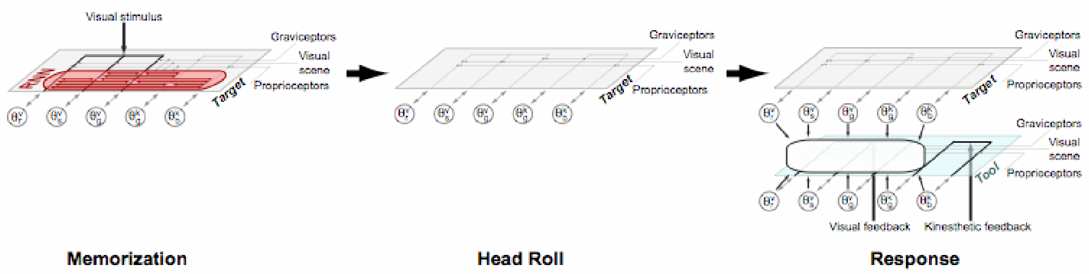

Fig.1 Sensory-motor integration model. Visual information about stimulus is combined with graviceptors, proprioceptors and visual scene information to build different internal representations. After the head roll the interposed Recurrent Neural Network is not functional.

like initiate a step or reach to an object, are characterized by a continuous trade-off between speed and accuracy to carry on the limb to a target. In many cases the need to perform the movement in short time may require a pre-planning of the action way before its initiation [1]. A way to consider movement preparation is to detach the activities of the main muscle involved in the action and analyze them within the window–time between the "go" signal and the instant of the overt action initiation; these muscle activities are called Anticipatory Postural Adjustments (APAs). The aim of the study is to analyze the behaviour of the APAs under Fitts' Law paradigm [2] to better understand how and when different movement parameters such as speed and accuracy are planned in advance before movement initiation [3]. Fitts' Law is an ad hoc model to test our hypothesis. The law defines movement time as linearly related with the ratio between the distance needed to reach a target and the target size such as:

$$MT = a + b * \log_2(2D/W) \quad (1)$$

Where (MT) is the time applied to reach a target, (D) is the distance needed to reach the target, (W) is the target size and (*a*) and (*b*) are empirical constants. In (1) $\log_2(2D/W)$ is called the index of difficulty (ID) that predicts that as long as the ration is constant, MT should remain unchanged. The hypothesis is that the assessment for a specific APAs modulation given the different task difficulties (ID, [2]) could be an indication for a pre-planning mechanism that accounts for the trade-off between speed and accuracy for gait initiation.

METHODS: Twelve expert ballet dancers took part in the experiment. They were instructed to perform a discrete movement as to point with the tip of the toe at a target (with width *W*) placed on the floor in front of them at certain distance, (*D)*. The instruction given was: "be as fast and as accurate as possible in your pointing movement" [4].

RESULTS: The kinematics results (movement time) revealed a non-linear relationship with the ID ($\log_2(2D/W)$), indeed movement time was linearly scaled with just movement distance. On the contrary, the two APAs parameters, onset and magnitude, were differently modulated with respect to the ID by separating short with long distances, namely, while for short distances both parameters were affected by the ID, for long distances just the magnitude was ID related.

CONCLUSIONS: The main results showed that during a whole body movement, such as gait initiation, the common speed-accuracy trade-off, known as Fitts' Law, was not followed. By analyzing the APAs, two different control strategies appeared for short and long distances. The results bring to light how a control strategy is selectively coupled and constrained by task parameters: movement time, distance and accuracy. The findings may have clinical relevance by modelling for an all body action the planning component with the perceptual-action relationship.

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Influence of Single Joint Perturbation on Interlimb Co-ordination During Human Gait

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INTRODUCTION: Interlimb co-ordination plays a vital role in both human and animal locomotion. However, little is known about underlying afferent feedback to interlimb co-ordination [1-8]. The aim of this study was to obtain evidence of the contribution of sensory afferents to inter-limb coordination during human treadmill walking by investigating reflex responses in muscles of the contralateral leg evoked by single joint perturbations applied to the ipsilateral leg.

METHODS: A semi portable robotic ankle actuator attached to the left ankle joint was used to randomly induce dorsiflexion and plantarflexion perturbations while the subject was walking on a treadmill at $3.5 kmhr^{-1}$. These perturbations were varied in either amplitude (± 4°, 500°/s , ± 6°, 500°/s and ± 8°, 500°/s) or velocity (± 6°, 100°/s, ± 6°, 300°/s and ± 6°, 500°/s). Three different phases of the gait cycle were investigated: early stance, late swing and double support of the ipsilateral (left) leg. To investigate the possible afferent contribution to the responses selective ischemic block of the ipsilateral leg was induced. Electrical stimulation of the tibial (TIB) and common peroneal (CP) nerve were applied to the ipsilateral leg to further elucidate the possible afferent feedback to contralateral leg muscle reflex responses. Stimulus intensity was submaximal to the strength required to evoke a maximal M-response during standing and the single pulse duration was of 0.5 ms.

RESULTS: Significant facilitatory responses were evoked in the contralateral medial gastrocnemius (cGM) [$F(2, 22) = 6.51$, $p = 0.006$] and biceps femoris muscles (cBF) [$F(2, 22) = 4.08$, $p = 0.03$] when velocity varying perturbations were applied in the swing phase of the ipsilateral leg. The onset latencies of cGM and cBF responses recorded during the swing phase varied from 69 to 103 ms depending on the type of perturbation. These responses in the contralateral leg were abolished by ischemic block of the ipsilateral leg. TIB and CP nerve stimulation during the swing phase of the ipsilateral leg resulted in contralateral soleus (cSOL) [p = 0.03 for TIB nerve stimulation] and tibialis anterior muscles (cTA) responses. The onset latencies of the responses ranged from 67 to 107 ms. No reflex responses were evoked when the ipsilateral leg was perturbed / stimulated in its stance phase. Perturbations / stimulations in the double support phase evoked no consistent responses.

CONCLUSIONS: The data indicate that single joint perturbations can cause reflex type activity in contralateral leg muscles. These responses are too early to be volitional and are phase specific. The reflex responses evoked in the contralateral leg muscles due to electrical stimulation further strengthens the hypothesis of involvement of muscle afferent feedback in interlimb co-ordination. The selective ischemic block indicates that the responses are likely to be mediated by large diameter afferents.

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Characterizing the determinants of limb preference for compensatory stepping in healthy young adults: implications for individuals with stroke

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INTRODUCTION: Compensatory balance control is critical in response to an external perturbation [1,2]. Specifically, change in support reactions, or reactions that involve movement of the limbs to adjust the base of support, are frequently observed in response to balance perturbations [3]. There is currently little understanding of the determinants of limb preference for reactive compensatory stepping. From our experience, the dominant limb used for voluntary steps will not necessarily be the preferred limb for compensatory stepping. In healthy individuals, we contend that the main factors for task-related evidence of limb preference in compensatory stepping are limb dominance and stance loading. Gaining further insight into limb preference for compensatory stepping is particularly important when attempting to apply knowledge to individuals with stroke, who typically stand with an asymmetrical weight distribution favouring their unaffected limb.

METHODS: Twelve healthy young adults (six men; mean age ± standard deviation: 27±6 years) volunteered for this study. Anterior and posterior compensatory steps were evoked using a weight drop system. Participants were informed that they would “receive a pull in either direction at any time” and to “respond as safely as possible to maintain balance”. There were two separate pre-perturbation task conditions: equal weight distribution (EWD), and asymmetric weight distribution (60% body weight over dominant limb; AWD). Time to foot-off was determined from unloading of vertical force on the force plates.

RESULTS: Eight of the 12 participants were right-leg dominant as measured by the Waterloo Footedness Questionnaire. In the EWD condition, participants stepped in 94% (47/50) of trials and of the trials with a step, 95.7% (45/47) of trials were taken with the dominant limb. Mean time to foot off for steps taken with the dominant limb was 513±126ms. In the AWD condition, where weight distribution was loaded on the dominant limb, compensatory stepping occurred in 92.7% (51/55) of perturbations and steps were executed with the dominant limb in 43.1% (22/51) of trials with a step. Mean time to foot off for steps taken with the dominant limb was 620±131ms.

CONCLUSIONS: Nearly half of the compensatory steps were taken with the dominant limb despite it being loaded and resulting in a delay in foot off time. These early findings suggest that limb dominance is a strong determinant for choice of compensatory stepping limb, even when weight distribution is asymmetric. Ongoing studies following from this paradigm are focused on individuals with stroke, for which limb preference and asymmetric loading present a unique challenge. Following stroke, there is a preference to stand with weight over the non-paretic limb, but this loaded non-paretic limb may also be the preferred limb to use for initial compensatory steps. The potential increase in time to foot-off, observed with healthy adults in this study, may pose even greater challenges to balance control when using compensatory stepping after stroke.

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Generalizability of perturbation-evoked cortical potentials: cortical activity linked to temporally-urgent responses

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INTRODUCTION: There is growing interest in understanding the extent to which the cortex participates in human postural control. Several studies have characterized the spatio-temporal profile of scalp potentials evoked by postural instability [1,2]. Recent reports indicate that the spatio-temporal profile of these evoked potentials may be generalizable; independent of the specific sensory and motor components of the task [3]. Such generalizability supports the notion that perturbation-evoked cortical potentials may reflect activity linked to event detection or error processing. If such potentials are truly linked to CNS processing, independent of the specific sensorimotor aspects of the underlying postural control, then they should also be present during the execution of temporally-urgent non-balance reactions. The purpose of this study was to determine whether the generalizability of evoked cortical potentials extends beyond tasks associated with postural instability by comparing the spatio-temporal profiles of perturbation-evoked cortical potentials with those evoked by non-postural stimuli.

METHODS: Temporally-urgent responses were evoked using two different paradigms. In the SIT condition, participants experienced postural instability in the lateral direction while sitting in a tilting chair. Compensatory stabilizing responses were executed with the right arm. In the GRIP condition, an instrumented block initially positioned between the thumb and index finger in a vertical alignment was released. Upon detection of this stimulus, participants were required to re-grip the block by executing a compensatory motor response (a ‘gripping’ or ‘catching’ response) with the thumb and index finger. Cortical activity was recorded using a 32-site electrode cap and averaged across thirty trials for each condition. Muscle activity was recorded from the anterior deltoid and first dorsal interosseous muscles for the SIT and GRIP tasks, respectively.

RESULTS: Consistent with previous studies, the cortical potentials (N1) evoked by instability in the SIT condition reached their peak amplitude between 100-150 ms following perturbation onset. In spite of the laterality of the motor responses, the potentials were largest under fronto-central electrode sites (FCz,Cz). The temporal and spatial characteristics of the evoked N1 responses were similar for the cortical potentials evoked in the GRIP task.

CONCLUSIONS: Importantly, consistencies in the spatio-temporal characteristics of the evoked cortical activity reveals that such activity is generalizable across tasks requiring temporally-urgent responses, irrespective of the specific sensori-motor components of the particular task and that such activity is not specific to the execution of postural responses. Ongoing analysis of the current data is focused on dipole localization in order to establish the source of these evoked potentials.

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Preserving postural stability while reaching beyond arm’s length

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INTRODUCTION: When performing reaching movements beyond arm’s length while standing, all four limbs participate in the task, involving at least 5 joints (Ankle-Knee-Hip-Shoulder-Elbow). The joints are combined in a functional unit consisting of a focal task (reaching a target with the hand) and a postural task (keeping the projection of the center of mass within the bipedal support area). The fact that the two tasks are part of the same functional unit is proved by anticipatory postural adjustments [1] and by the statistical analysis of whole body reaching movements [2-3] that shows a strong coupling among the joints. However, how the brain combines the focal task with the postural task is still an open question that we address in this presentation by means of a computational model.

METHODS: We combined two models: 1) a postural stabilization model and 2) a trajectory formation model capable to account for kinematic redundancy. The former model takes into account that the stiffness of ankle muscles is below the critical value of gravity-induced toppling torque and is based on a robust intermittent control mechanism (figure 1) that is little sensitive to propagation delays [4-5]. The latter model (figure 2) is based on the Passive Motion Paradigm [6] and has been proved to be effective in the control of highly redundant humanoid robots [7-8].

RESULTS: Preliminary simulation results are analysed from the point of view of stability and consistency with experimental data. In particular the model can reproduce the empirical fact that when reaching forward also the center of mass is shifted forward. The model can also accommodate task-related constraints in a quite natural way.

CONCLUSIONS: The model is general enough to address a variety of coordination tasks that involve kinematic and postural constraints.

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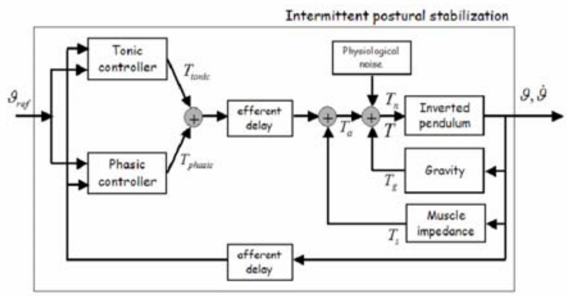

Fig.1 Intermittent postural controller

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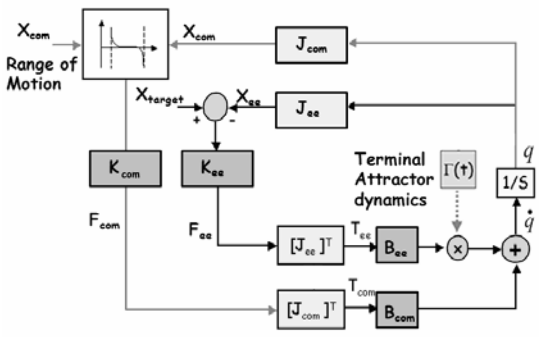

Fig. 2 Multijoint controller

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Obstacle avoidance responses to a startling auditory stimulus applied at different delays

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INTRODUCTION: A startling auditory stimulus can speed up voluntary reactions when it is applied at the same time as the imperative signal, a phenomenon termed StartReact. The suggested physiological mechanism underlying the StartReact effect is that motor programmes are represented in subcortical structures where they are accessible to a startling stimulus. Alternatively, the StartReact effect may also be attributed to the joint stimulation of different sensory modalities (intersensory facilitation). Queralt et al (2008) studied the effects of a startling auditory stimulus in obstacle avoidance during walking and found evidence for both physiological mechanisms playing a role [1]. The aim of the present study was to disentangle the contribution of these mechanisms in the preparation and execution of obstacle avoidance reactions with startles.

METHODS: Ten healthy young adults walked on a treadmill at a speed of 3 km/h. An obstacle was suddenly dropped in front of the left leg. The experiment consisted of 160 trials and there were four conditions. Obstacle avoidance without startle (OA) was performed in 60 trials, equally divided over 3 step cycle phases (late stance (LSt), early swing, and mid swing). Obstacle avoidance with startle (OA-SAS) was performed in 20 trials, at delays of 10, 40, 70 and 100 ms after LSt obstacle release. In 20 trials a startle was given at the same 4 delays with the obstacle present, but without its release (Stationary obstacle, StO-SAS). The other 60 trials were walking trials in which the obstacle did not fall and no startle was given. EMG activity was recorded from the biceps femoris (BF), which is the prime mover in the obstacle avoidance task. Onset latencies were determined relative to obstacle release and to startle delivery. To determine at which instant the combination of auditory input and visual information of obstacle motion started to have a facilitatory effect, the point of divergence between EMG amplitudes of OA-SAS and StO-SAS trials was determined.

RESULTS: The results showed that there is a critical time window in which the StartReact phenomenon can be elicited. Compared to OA trials, onset latencies were significantly shortened when the auditory startle was delivered in OA-SAS conditions with a delay of 10 and 40 ms (onset latencies of 125 ms and 135 ms, respectively). However, if the startle was applied at delays of 70 ms and 100 ms, differences were not significant. In OA-SAS and StO-SAS trials, onsets relative to the startle were not different, except for the 100 ms OA-SAS condition. In OA-SAS trials, EMG amplitude started to differ from StO-SAS at approximately 120 ms after obstacle release, whereas responses to release of the obstacle in the absence of a startle were only observed after a mean of 167 ms.

CONCLUSIONS: The findings that the startle speeded up OA responses and that responses occurred at a fixed time relative to startle release strengthen the hypothesis of subcortically stored motor programmes, which can be released by a startling stimulus. Furthermore, when a startle is applied with obstacle release, obstacle motion is starting to facilitate the response after approximately 120 ms, which is some 50 ms before it becomes sufficient to release the motor programme in the absence of a startle.

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Anticipating gait initiation leads to early activation of the motor programme for locomotion

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INTRODUCTION: In a context of reaction time task experiments, voluntary reactions can be speeded up by a startling stimulus delivered at the same time as the imperative signal, a phenomenon termed StartReact. MacKinnnon et al. (2007) reported the StartReact phenomenon in gait initiation which suggests that the prepared motor programme for gait initiation is stored and launched from subcortical neural structures [1]. However, little is known about the relation between the launch of the gait initiation motor programme and the generation of the ensuing walking pattern. Walking is a repetitive sequence of muscle activation that is maintained quite automatically. This cyclical pattern and other rhythmical activities are generated by neural networks which are specialized in repeating particular actions over and over again [2]. The term central pattern generator has been used when refering to such neural network for locomotion. The aim of the present study is to examine how the two motor programmes respond to an experimental manipulation of the timing of gait initiation.

METHODS: Eigth healthy adults performed a rapid initiation of gait at the appearance of a visual imperative signal. In some trials at random, an unexpected startling auditory stimulus was delivered simultaneously with the imperative signal. Subjects were requested to perform at least 3 complete steps. A total of twenty trials (fifteen without startle and five with startle) were collected. We recorded the EMG activity of tibialis anterior, soleous, rectus femoris and biceps femoris of the leg that initiated gait as well as the toe-off and heel-on time points.

RESULTS: Latency of gait initiation and gait pattern related events showed a significant shortening in trials with startle. Time differences between control and test trials ranged from 40 to 150 ms for gait initiation related events. On the contrary, the events related to gait pattern had the same time difference (around 200 ms) as the last event of gait initiation.

CONCLUSIONS: The fact that the effects of SAS were limited to gait initiation suggests that the programme for gait pattern had not been launched at the time when the imperative signal was delivered. Additionally the proportional advancement of the gait pattern sequence to the end of gait initiation supports the view that gait initiation may actually generate the inputs needed to trigger the gait-pattern sequence.

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Centre of mass control during volitional stepping

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INTRODUCTION: The regulation of the relationship between the centre of mass (COM) and base of support (BOS) is a complex control problem. During compensatory or voluntary stepping, the capacity to effectively decelerate the COM after foot-contact is likely an important determinant of dynamic stability control [1]. Despite the potential importance of the events surrounding foot contact, little is known about COM control during the terminal phase of stepping tasks. As a precursor to exploring compensatory stepping, the present study is delimited to single step voluntary movements, in which there is the opportunity for feedforward control. It is proposed that there should be little disparity between peak and final COM displacement, in both anteroposterior (AP) and mediolateral (ML) directions, during a single step of preferred length and width. Under- or overshoot of the final position is thought to result from discontinuities between voluntary movement planning and execution, which must be corrected by compensatory strategies on foot contact to maintain balance. The capacity for feedforward control during voluntary stepping should also afford the potential to reduce any incongruity, with repeated trials using similar step dynamics. We also evaluated COM control at foot-contact when there is intended variation in step length and/or step width. Our initial intention is simply to characterize the trajectory of the COM during various combinations of preferred and altered step parameters, to better understand the precision of this control. The long-term objective of this work is to develop an understanding of the kinetic determinants underlying the control of the COM during stepping that may elucidate the factors potentially associated with fall risk.

METHODS: A motion analysis and force plate system was used to record 3D kinematic data and reaction forces and moments under both feet during quiet stance as well as from the stepping limb upon heel strike. The lower extremity was modelled as a rigid, linked-segment system. The total body centre of mass was calculated as a weighted average of all body segments, according to each segment's mass proportion. Participants were to take part in three conditions in random order, where they took a single step with their preferred leg. These conditions consisted of ten trials of various combinations of increased step length and width, relative to the preferred step parameters. Ten trials, using the preferred step parameters, were collected at both the beginning and end of the testing session to aid the analysis of learning effects.

RESULTS: On average, there was overshoot of the final COM position in 87 and 88% of trials in the AP and ML directions, respectively. There were no differences between conditions in the magnitude or frequency of overshoot or in the degree of COM overshoot with practice over repeated trials, as evaluated using correlation analysis and by comparing first and last block of trials. Further analysis, revealed no relationship between COM position overshoot and peak contralateral COM displacement before stepping limb toe-off, COM velocity at foot-contact, step width, or length.

CONCLUSIONS: The discrepancies between the peak and final COM displacement did not vary by stepping condition, suggesting that COM control during volitional stepping is not dependant on step dynamics or the COM velocity profile. These differences did not diminish with repeated trials of similar step dynamics. Moreover, as the magnitude of disparity did not correlate with variables occurring before heel-contact, it is possible that COM control, even during voluntary stepping, is highly dependant on feedback obtained from the stepping limb on foot-contact [2]. The next stage of this work is to explore such control of the COM at foot-contact when stepping is reflexively-evoked.

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Balance control strategy during a forward lunge step

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INTRODUCTION: Falls among the elderly are a common event that can result in serious injury. It has been revealed that increased medio-lateral sway is associated with recurrent fallers [1-2]. Some experiments have employed assessments, such as the maximal step length test in the forward direction [3]. This test was signified to be a good predictor of mobility, performance, frequency of falls, self reported function and balance confidence [3]. Standing balance control reveals a change from greater antero-posterior displacement to greater medio-lateral displacement as individuals age [4]. Exercises that challenge medio-lateral stability, such as the forward lunge, may be a useful intervention in preventing falls among the elderly. The forward lunge has been used in many different exercise programs designed for strengthening; however the postural and balance control aspects of the lunge have not been studied. The current study investigated the balance strategy used during a forward lunge. The first step in understanding the effects of the forward lunge on balance in an elderly population is to understand how young individuals successfully complete the task.

METHODS: Seven healthy young individuals and one elderly individual were analysed while completing 10 forward lunges, five with each leg as the lead limb. Full body motion capture was collected for all trials by a 7-camera Vicon system. AMTI force plates were also used to collect ground reaction forces. Data was processed and analysed using Plug-in Gait.

RESULTS: During a forward lunge, data from the young individuals suggests that peak center of mass displacement in the medio-lateral (M-L) direction has a positive relationship with center of mass variability in the M-L direction. Both of these variables have positive relationships with step width variability, peak trunk velocity in the M-L direction and peak pelvis velocity in the M-L direction. The single elderly individual exhibited a greatly reduced step length. The elderly individual also demonstrated an increased peak posterior excursion and increased variability of the center of pressure. All other variables for the elderly individual fell within the range of the young individuals.

CONCLUSIONS: Young individuals demonstrated that as center of mass variability increases and overall instability increases, as shown by increased velocities at the trunk and pelvis, step width variability also increases suggesting that foot placement is used as a means to regulate trunk stability. The single elderly individual exhibited a more cautious approach to the lunge revealed by a greatly reduced step length.

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Posture-Locomotor Interactions are equivalent in the AP and ML directions

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INTRODUCTION: Optic flow has been demonstrated to influence postural sway and gait characteristics, contributing to the stability of locomotion. However, most studies focus on parameters related to the gait cycle (e.g. stride length and stride frequency) [1]. Here we show that there is significant coupling to vision at frequencies other than the gait cycle, suggesting an avenue to explore the interaction between posture and locomotion. We asked if there is a difference in this interaction between stimuli displayed in the anterior-posterior (AP) and medial-lateral (ML) directions.

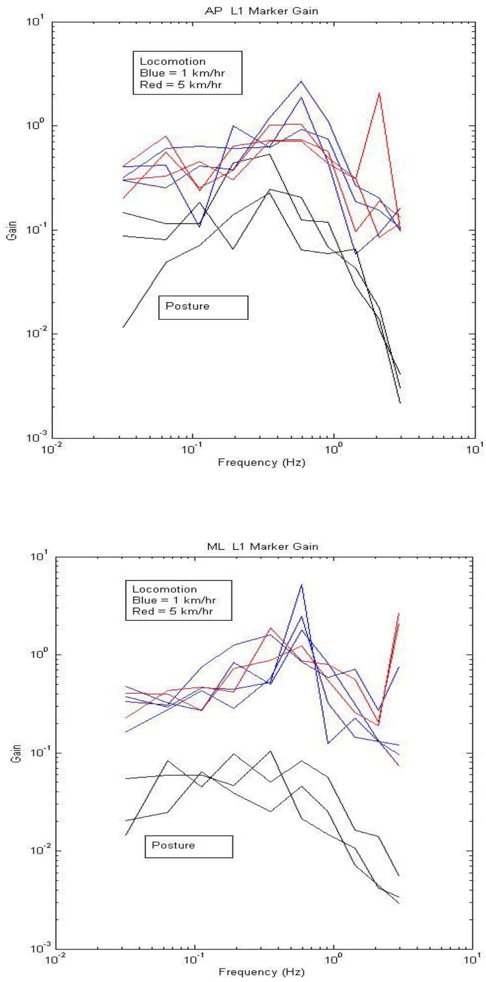

Fig. 1 Representative single subject AP and ML gain for marker L1, 3 trials in each condition

METHODS: Subjects aged 18-25 years viewed a visual scene of randomly orientated triangles projected onto a widescreen LCD TV while walking on a treadmill at either 0, 1, or 5 km/hr (3 trials/condition). Goggles were worn by all subjects to limit peripheral vision. The visual drive consisted of translational optic flow in the A-P or M-L direction with multiple frequencies. Kinematic data (Optotrak) from 11 anatomical positions and surface EMG from 12 muscles were recorded. Power spectral densities (PSD) and cross spectral densities (CSD) were computed to identify coupling of segment angles and joint position to the visual stimulus.

RESULTS: Visual stimulation in the AP and ML directions led to equivalent results, indicating similar coupling of body segments to vision. Gain of translational joint positions relative to the visual stimulus increased during locomotion by a factor of 10 when compared to quiet stance in both the A-P and M-L directions, suggesting that body segments were more strongly coupled to vision during locomotion than during quiet stance (Fig. 1).

CONCLUSIONS: Stronger coupling to the visual display was suggested by higher gains during locomotion than during quiet stance. Moreover, visual stimulation produced similar results across conditions, suggesting that the interaction between posture, locomotion and sensory coupling is equivalent in the AP and ML directions. These results have implications for studies suggesting that control of locomotion in the ML direction is qualitatively different (active vs passive) than in the AP direction [2].

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Is there premotoneuronal modulation of soleus H-reflex by rhythmic arm swing?

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INTRODUCTION: In studies exploring the interaction between upper and lower limbs it was found that Soleus H-reflexes are suppressed by rhythmic arm movements [1-4]. Furthermore in some of these studies [2,3] it was shown that there was a phase-dependent modulation of the reflexes while others, using cycling arm movements, did not find this [4,5]. In order to be under the control of central gating the modulation of the reflexes should differ from the modulation of the background. Hence, the question remains whether phase-dependency is present due to arm movements and whether the modulation is premotoneuronal (independent of modulation of background activity).

METHODS: To reexamine this issue a study is needed in which the variations in background EMG are compared to those seen in the H-reflexes sampled over many different phases of the cycle. Subjects were sitting while they made rhythmic arm movements of different types either in the sagittal plane (in one arm only, bilateral in phase or alternating) or in the frontal plane (bimanual abducting), guided by a metronome. Background EMG in soleus was measured as RMS in a 50 ms period prior to stimulation and compared to the peak to peak H-reflex amplitude. Stimuli were given in one of eight phases during the arm cycle.

RESULTS: Soleus H-reflexes were suppressed by the arm movements as expected. In addition in some conditions (ipsilateral arm swing) there was a phase-dependent modulation of the H-reflex amplitude. This modulation did not follow the changes in soleus background activity which was kept constant.

CONCLUSIONS: The present findings confirm the general observation that H-reflexes are suppressed by arm movements. Evidence for a phasic modulation of arm rhythm generators on these reflexes was also present during sitting. This premotoneuronal gating of H-reflexes may be due to phasic presynaptic inhibition, as suggested by others [6].

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Gravity and interactive torques: wired by competition in stepping over obstacle

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INTRODUCTION: During multijoint movement such as stepping over an obstacle, gravity and intersegmental torques guide the way the movement fulfils. To asses the extent to which gravitational torques and intersegmental dynamics are represented in control signals during a multijoint movement, we artificially removed gravity using parabolic flight. This situation is of interest because the leg movement requires predicting the magnitude of the i) gravity forces for the segments which are the most relying on gravity torques and ii) interactive torques for the segment which benefits almost completely by the motion of neighbouring segments. One would expected segment trajectory the most relying on gravitational force to be altered overtime when performed in microgravity and lower limb segment which benefits of the interaction torques between segments to remain invariant when removes gravitational force.

METHODS: Stepping over an obstacle was performed in microgravity (μG) and normogravity (nG) environments Seven subjects participated in the experiment. Segments, angular joints displacements and segment-interaction analyses were performed. The data were analyzed using Wilcoxon matched-pairs signed-rank test to assess the differences between conditions (μG and nG).

RESULTS: All subjects succeeded in producing the required obstacle avoidance movement in both gravitational environments. When gravity is removed, the hip net joint torque increased (Fig 1), due to the missing downward force of gravity. This result could be explained by the fact that the thigh segment was the most affected by the gravity torque (Fig 1). When the gravitational torque became negligible as for the foot segment, the ankle torque was maintained similar in μG with respect to nG (Fig 1). As the foot segment benefits from the interaction torques from the shank and thigh segments, gravity becomes pointless within the control process.

CONCLUSIONS: These results fit to the idea that less important "weight" lose out in the competition by being considered as non relevant by the control process.

ACKNOWLEDGEMENTS: This study was financially supported by the CNES (Centre National d'Etudes Spatiales) and the Natural Science and Engineering Research Council (NSERC) of Canada while the Fonds de la Recherche en Santé du Québec (FRSQ) is also acknowledged for scholarship award to F. Prince.

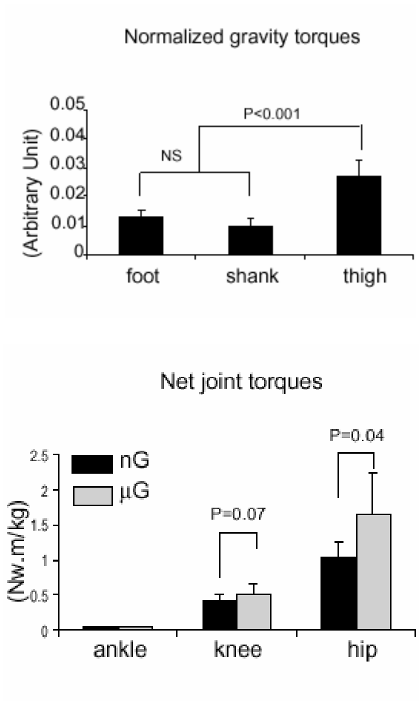

Fig.1 The top histograms show the mean peak magnitude of the Gravity torques after normalization to the segment's mass and the right histograms, mean peak torques for the three joints.

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Dual task performances can be improved in patients with dementia

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INTRODUCTION: Attention-related deficits are associated with motor deficits and may be related to the high fall and injury risk in patients with dementia [1]. So far no dementia-specific physical training intervention to improve dual-task (DT) performance has been performed in patients with dementia [2]. The purpose of this study was to document the effect of a specific DT-training.

METHODS: 62 geriatric patients with mild to moderate dementia confirmed by established international diagnostic criteria took part in a 10-week randomised controlled trial. Subjects in the intervention group (IG) underwent a 10-week (2 times/week) progressive motor-attention-training under single-task (ST) and DT conditions. Subjects in the control group (CG) attended an unspecific low-intensity exercise group. Measurements: Gait performance (maximum gait speed, cadence, stride length, stride time, percent single support of stride-time) was documented by computerized analysis (GAITRITE) and cognitive performance (semi-automated calculation steps [serial 2 forward=S2] and non-automated calculation [serial 3 retro=S3]) was digital-recorded under ST and DT conditions. Relative motor and cognitive DT costs were computed (to their respective ST condition). A total DT burden was calculated representing the overall performance loss (motor+cognitive).

RESULTS: As an effect of the DT-training the IG compared to the CG improved in relative DT motor performance significantly ($P<0.001$-0.007 [all selected gait parameters except of stride time) during DT-S3 conditions (Range of improvement: 8.70-21.65%). Also total DT performance improved (20,60%, $P=0.026$) compared to CG, but not cognitive performance. During semi-automated S2-DT conditions no significant effects could be obtained.

CONCLUSIONS: The presented dementia specific DT–based exercise program is effective to reduce the DT burden in patients with mild to moderate dementia.

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Impact of impaired executive function on gait stability

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INTRODUCTION: Executive dysfunction contributes to gait changes but the precise mechanisms are still poorly understood. Dual-task related gait changes, depend in part on the capacity to appropriately allocate attention between tasks performed simultaneously and are mainly related to executive deficits [1]. Whilst many studies analyzed the influence of executive function on gait, none of these reports compared specifically the gait performance of demented subjects with and without dysexecutive syndrome. Acquiring more information about dual-task interferences in demented subjects with and without IEF could add to our understanding of IEF-related gait instability. This study aimed to describe the impact of dysexecutive function on gait stability in subjects with dementia using dual-tasking.

METHODS: Mean values and coefficients of variation of stride time while only walking and while walking and backward counting (dual-tasking) were measured using a GAITRite-System® in 18 subjects with dementia and impaired executive function (IEF), in 16 subjects with dementia and intact executive function, and in 22 non-demented subjects as controls. Gait measurements were made according to the guidelines for clinical applications of spatio-temporal gait analysis in older adults [2]. Dementia severity was measured with the Mini-Mental State and the Mattis dementia rating scale (DRS) in the demented subjects. Demented subjects were separated into 2 groups (i.e. with and without IEF) according to the Frontal Assessment Battery (FAB) and the Behavioral Scale of Frontal lobe dysfunction.

RESULTS: There were no significant differences between groups for age, sex ratio, use of psychoactive drugs, and number of chronic diseases. Etiologies of dementia significantly differed between groups ($P<0.001$). In the demented subjects without IEF, probable AD was the only diagnosis, whereas mixed AD/VaD was the main diagnosis in the demented subjects with IEF. Stride time, and particularly its variability, significantly increased while dual-tasking ($P<0.05$). IEF was related to both stride time and stride time variability during walking only ($P<0.05$) and to even more gait changes while dual-tasking compared to non-demented subjects and demented subjects without IEF ($P<0.001$). Univariate linear regression showed a significant association between a low FAB score and a high stride time variability while walking only ($P=0.005$) but not while performing the dual-task condition ($P=0.083$).

CONCLUSIONS: IEF has been implicated in gait changes during only walking and dual-task conditions. This finding confirms that executive functions are essential to gait control and, may partially explain gait instability observed in demented subjects. In a practical context, these findings strongly indicate that stride time variability may be considered as a good parameter to evaluate executive control of gait in patients with dementia.

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When ergonomy and posture help academic achievement

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INTRODUCTION: Several surveys have shown how profitable the use of ergonomic furniture can be as regards the amount of energy engaged on the regulation of posture during the day, as regards the improvement of the eye-posture reflex. Recently, Viguier showed the impact of furniture on the posture of children at junior high school. The use of ergonomic furniture is even prescribed in the treatment of dyslexia. The purpose of this presentation is to bring forward this topic notably for children without dyslexia related to cognition.

METHODS: 122 children (60 G, 62 B, age 9 $\pm$ 1.5) were paired and split into 2 homogenous groups according to age, sex, height, and former school results. The experimental group with ergonomic furniture and test group with classic furniture (either new or used) are in the same class so that both groups attend the same lessons with the same teacher at the same time.

RESULTS: : Based on multiple varied analyses, the impact of ergonomic furniture is clearly significant on: copying and the time spent on completing the Rey figure (R^2=0.34, p= 0,001), most focus parameters (R^2=0,28 ; p= 0,006), reading effectiveness (+31% , R^2 = 0,18, p = 0,05), well-being (R^2 = 0,32, p = 0,002), the decrease of tiredness (R^2 = 0,19, p = 0,05).

CONCLUSIONS: Girls are mostly the ones who benefit from this impact as early as first use. This could indicate that a modification of the posture has a direct influence on young girls notwithstanding any placebo effect.

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Relationship between standing balance and white matter changes in individuals with dementia and cognitive impairment

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INTRODUCTION: Previous studies have reported impaired balance and an increased rate of falls in individuals with white matter signal abnormalities (WMSA) observed on brain magnetic resonance images (MRI) or computed tomography (CT) scans [1]. The few studies to date that have employed quantitative methods to evaluate the exact nature of this balance impairment were inconclusive [2]. It is possible that the inclusion of a relatively healthy cohort with few white matter changes led to these inconclusive findings. The purpose of this study is to explore the relationship between WMSA and quantitative measures of standing balance in a cohort of individuals with varying levels of cognitive impairment.

METHODS: Volunteers were recruited from a cognitive neurology clinic. All subjects were able to stand independently without use of an assistive device. Data from an initial sample of 23 individuals are presented here (52-93 years old; 10 women; 15 with dementia, 5 cognitive impairment, 3 not cognitively impaired). Subjects stood on a force plate under three conditions: eyes open, eyes closed, and while leaning maximally forward, backward left and right (functional stability margins test). Each trial lasted 60 seconds. The area, 2-dimensional path length and medio-lateral (ML) and antero-posterior (AP) root mean square (RMS) of the centre of pressure position were calculated for the two static conditions. The maximal excursion of the centre of pressure in the AP and ML directions was calculated for the stability margins test. Clinical MRI and CT scans were rated for the presence of WMSA on the Age-related White Matter Change scale (ARWMC) [3] by a trained image analyst who was blind to subjects' clinical profiles. The relationships between ARWMC score and each balance measure were tested using age-adjusted linear regressions.

RESULTS: Sway path length showed a positive association with ARWMC score with eyes open (slope=0.61mm increase in path length per 1 ARWMC point; p=0.021) and a trend toward such an association with eyes closed (slope=0.88; p=0.096); that is, individuals with WMSA were more likely to show an increased path length. There were no associations between ARWMC score and sway area or RMS of sway. Likewise, no trends were observed for functional stability margins.

CONCLUSIONS: White matter changes, resulting in WMSA visible on brain images, appear to be associated with increased 2-dimensional sway path length and, therefore, increased speed of postural sway. Such changes in the control of standing balance could lead to an increased risk of falls for individuals with WMSA. Further research is required to investigate the specific mechanisms underlying the association between white matter changes and impaired postural control.

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Relationship between white matter change and gait characteristics during single and dual tasking in older persons with cognitive impairment

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INTRODUCTION: Cerebral age-related white matter change (ARWMC) is a ubiquitous neuroradiological finding in older adults. While previous studies suggest that ARWMC is associated with gait impairment in healthy older adults, there is a paucity of studies that examine this relationship in persons with cognitive impairment and use quantitative gait assessment. Therefore, we explored the relationship between spatiotemporal gait characteristics and ARWMC in cognitively impaired adults during walking at preferred speed, fast speed, and during self-paced walking while performing a cognitive task.

Methods: Ambulatory participants with memory-related cognitive impairment were recruited from a cognitive neurology clinic. ARWMC was assessed using the scale of Wahlund et al. [1] (scores range from 0-30, with 0 indicating no ARWMC) and using 1.5 T, 3D MRI images. Gait was evaluated using a 4.3m GaitRite walkway during 3 walks for each of the 3 conditions: preferred speed, fast speed, and self-selected speed while incrementally counting backwards. Mean values and variability of the following gait parameters were examined: speed, stride length, stride width, stride time, and double support time. Gait differences between groups dichotomized by ARWMC scores were evaluated using Mann-Whitney U tests and Spearman correlation coefficients.

Results: For the 14 patients that met inclusion criteria, diagnoses included Alzheimer's disease (n=8), mild cognitive impairment (n=5), and vascular dementia (n=1). Participants' mean age was 72 (range: 52-89), the median Mini-Mental Status Exam score was 25 (13-28), and the median ARWMC score was 3 (0-6). For all analyses, patients were dichotomized by ARWMC scores ≤3 and >3. Average preferred, fast and dual tasking gait speeds (m/s) were 0.96, 1.42, and 0.72 respectively. The mean preferred walking speed was slower (difference of 0.3) for patients with ARWMC >3 (p=0.02). Fast walking speed showed a trend toward being slower (difference of 0.38) in patients with ARWMC >3 (p=0.053). Mean dual task walking speeds were not significantly different (difference of 0.3) between groups (p=0.12). In addition, ARWMC was negatively correlated with preferred speed (r=-0.65, p<0.01), fastest speed (r=-0.54, p<0.01), stride length during preferred speed (r=-0.59, p<0.05), and showed a trend toward association with stride time variability at fast speed (r=0.43, p=0.06). Both gait speed and stride length during dual tasking showed a trend toward negative association with ARWMC (r=-0.47, p=0.06; r=-0.48, p=0.06 respectively).

Conclusions: Higher ARWMC scores were associated with reduced stride length, stride time variability, and slower preferred, fast and dual tasking gait speeds. Previous studies suggest that these gait characteristics impair mobility and increase fall risk [2]. In this ongoing project, we will further investigate links between gait, dynamic balance, cognition, age and ARWMC, as better elucidating factors associated with poorer gait quality in persons with cognitive impairment could help to identify patients who may particularly benefit from interventions aimed at preserving safe and efficient ambulation.

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Gait characteristics in elderly persons with intellectual disabilities

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Introduction: Maintaining mobility is an important aspect of healthy aging. In persons with Intellectual Disabilities (ID) the aging process starts early and, in this perspective, an early decline of gait can be expected. The aim of this study was to describe the gait in older persons with ID and to compare their temporal gait characteristics with existing data from other studies. Furthermore, an exploration of the possible factors that determine whether a person with ID will have problems with walking was completed.

Methods: In this retrospective cohort study of 32 persons with ID, aged 44 years and older, loading characteristics were examined by means of the Computer DynoGraphy system® (Infotronic, The Netherlands) during 20 seconds walking at preferred speed. In addition, information about the severity and cause of ID ('diagnosis') was obtained from the medical files. The parameters that were studied were cadence, the percentage of double support time (DST) and temporal asymmetry (100 * (Stance time left – Stance time right) / (Stance time left + Stance time right)). The results were compared with values obtained from the literature on mentally healthy elderly persons. Stepwise backwards linear regression was used to determine whether age, severity of ID (mild, moderate, severe, profound according to the ICD-10) and/or diagnosis (genetic defect, acquired brain damage, unknown cause of ID) could explain differences in gait characteristics.

Results: The observed group average cadence of 102 steps/min was just within the normal values ranging from 100-120 steps/min [1-3]. The persons with ID, however, displayed more temporal asymmetry (4.35%) compared to the healthy population (0.91%) [4]. A second large difference between mentally healthy persons and the ID group concerned the percentage DST. The persons with ID showed on average 37% DST, compared to ~25% in the general healthy population and 32% in frail elderly persons [2,3]. Hence, whereas the overall timing of the steps in persons with ID was still within normal values, the DSTs were longer which was probably related to a lower walking velocity [3]. Indeed, of 11 subjects with ID walking velocity was available (on average 1.07 m/s) which was at the lower limits of normal walking speed [5]. When relating the percentage DST of these subjects to their walking velocity, lower velocities were indeed associated with longer DSTs (r_s = 0.73, $p<0.05$). No significant associations were found within the ID group between diagnosis, severity of ID or age as independent variables and temporal asymmetry, percentage DST and cadence as dependent variables.

CONCLUSIONS: Elderly persons with ID show abnormal gait characteristics compared to mentally healthy elderly persons in terms of longer double support time, which is associated with lower walking speed. They also show more asymmetry, irrespective of diagnosis and severity of ID or age. Further research should elucidate the factors that contribute to the observed gait abnormalities.

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Correlation dimension (D_k) estimates of human postural sway due to aging

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INTRODUCTION: Humans exhibit complex postural oscillations during quiet stance. Nonlinear dynamical properties of Center of Pressure (CoP) signal have been searched by computing the scaling exponent H, the correlation dimension and the largest Lyapunov exponent, fractal properties and long range correlations through detrended fluctuation analysis, and entropy measures in elderly subjects. Nevertheless, control of human upright stance is still a mystery, as CoP signal demonstrates stochastic characteristics as well.

METHODS: CoP_x signals in antero-posterior direction were recorded from 28 healthy subjects (14 male and 14 female) who were equally divided into 4 groups according to their ages; Group (G)1: 6-15 yr, G2: 20-40 yr, G3: 41-60 yr, and G4: 65+ yr. 5 successive 180 seconds long trials were recorded from each subject. Linear analysis involved variance and PSD estimates of the signal. The stationary and ergodic characteristics were searched by applying a non-parametric statistical test (Run test) and Ensemble Averages Method respectively. The nonlinear analysis consisted of computing the correlation dimension estimates (D_k) from stationary signals by using the method of time delays (τ). The optimum τ for expanding the reconstruction of the attractor has been found by using the average displacement method [1].

RESULTS: Standard deviations and PSD estimates were found to be significantly different on subjects ($p<0.000$). The Run test results showed that 4 out of 140 trials were nonstationary, which belong to four different subjects. Ensemble Averages Method revealed that 11 of the 28 subjects had stationary and ergodic signals. D_k estimates converged at 112 of 136 trials (Figure 1). Friedman test showed that the groups are not different in the number of converged trials. ANOVA test applied to unbalanced D_k data with multiple comparisons has further revealed that G4 is significantly different than the other three groups ($p<.000$).

CONCLUSIONS: D_k values saturated in an embedded dimension *m,* being larger than 8, which points to two-segment pendulum dynamics irrespective to subjects' ages. The converged non-integer D_k estimates suggests fractal structure of human quiet stance. The order of the dynamics was higher in children and elderly groups while the variability in the order of the dynamics was smallest in the first group pointing to a homogenous postural control strategy used. On the contrary, the elderly group was inhomogenous in the postural control strategy selected with an order of dynamics changing from 3.1 to 5.28 pointing to two-segment and three-

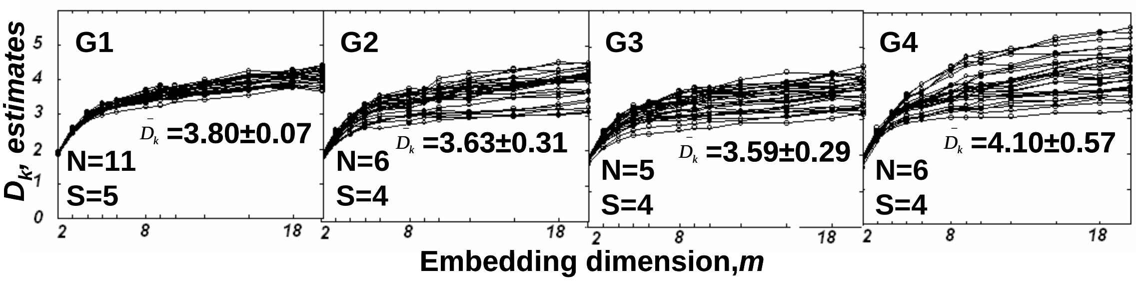

Fig.1 Converged D_k estimates. N denotes the number of not-converged trials, S stands for the number of the subjects who demonstrated at least one not-converged trial, D_k is the mean and the standard deviation of D_k estimates for the converged trials respectively in each group.

segment pendulum dynamics respectively.

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Motor-equivalent control of step parameters, center of mass, and head orientation: Uncontrolled manifold analysis of treadmill walking in early adulthood and normal aging

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INTRODUCTION: Human walking is a complex motor activity, requiring the coordination of many biomechanical degrees of freedom, subject to multiple functional constraints, such as balance, orientation and forward progression. Gait control has mostly been addressed by analysis of „output variables“ (e.g., step length or head stability), which have been found to show changes related to normal human aging. However, little is known about the interlimb coordination, or motor synergies [1], underlying stabilization of these variables.

METHODS: Sixteen young men (mean age ± SD: 25.8 ± 2.7 years) and sixteen older men (71.4 ± 2.3 years) walked on a motorized treadmill at individually adjusted speeds (preferred speed, ±20%), as well as five prescribed walking speeds (2.4, 3.0, 3.6, 4.2, and 4.8 km/h). Whole-body kinematics were recorded (VICON). We used the uncontrolled manifold (UCM) approach [2] to analyze the structure of variability in “step postures” (body postures at the time of heel strike) with respect to several potential control variables: step length, step width, center of mass position and head orientation. By means of a biomechanical forward model, postural variability was partitioned into goal-equivalent and non-goal-equivalent components (GEV, NGEV). In the UCM framework, a specific variable is assumed to be controlled synergistically when GEV is statistically greater than NGEV. Moreover, the strength of the synergy can be quantified by a synergy index, defined as the ratio between GEV and NGEV [3].

RESULTS: Preliminary analyses regarding the structure of postural variability revealed synergistic control of each of the abovementioned variables (GEV>NGEV). Older adults showed weaker synergies for step length control than younger adults. Synergy indices increased with walking speed for step length, but decreased for step width. We found no systematic effects of age group or walking speed on the control of center of mass position and head orientation.

CONCLUSIONS: To our knowledge, this is the first study addressing the flexibility/stability aspect of motor synergies in human walking in an age-comparative way. Analyzing step postures with the UCM approach, we found evidence for (a) synergistic stabilization of a number of potential control variables, and (b) age-associated reduction in synergies related to step length control. The results regarding motor-equivalent control of step parameters provide additional justification for the use of step-related variability measures as indicators of gait instability [4]. A better understanding of the control structure of „normal“ walking may be relevant for describing and interpreting developmental or pathological changes in gait patterns.

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Ageing and gait variability – The Tasmanian study of cognition and gait

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INTRODUCTION: Greater gait variability may be associated with risk of falling and with clinical diseases such as Parkinson’s disease [1, 2]. However, few studies have examined how variability changes with age in older populations. The study of how gait variability is affected by age may lead to a better understanding of the mechanisms underlying falls in older people and allow preventative interventions to be targeted at appropriate age groups. The aim of this cross sectional study was to examine associations between age and measures of gait variability in a population-based sample of older adults.

METHODS: Men and women aged 60-86 years (n = 411) were randomly selected from the electoral roll. Step length, step time, step width and double support time (DST) were recorded with a GAITRite walkway. Variability for each gait measure was the standard deviation of the measurements recorded during six walks. Regression analysis was used to model the relationship between age and gait variables, first adjusting for height and weight and finally adjusting for gait speed. Effect modification by sex was examined using an age × sex interaction term.

RESULTS: The average age of the sample was 72 (SD 7.0) years, with 42.9% being female. The average walking speed of the sample was 113.9 cm/sec. Increasing age was positively associated with greater variability in each gait measure for men and women ($p<0.05$). Among women, the association between age and step time variability was stronger for older women ($p<0.05$). Adjusting for gait speed reduced the magnitude of the age coefficient by 62-86% for temporal variability measures, with little change in the coefficient of speed (range 4-10%). The magnitude of the age coefficient reduced by 25% for step length variability and changed by 7-15% for step width variability after adjusting for speed. No significant interactions between age and sex were observed for any of the gait variables.

CONCLUSIONS: These are the first results describing associations between age and a range of temporal and spatial gait variability measures in a large population-based sample. Greater age was associated with increased gait variability. Linear relationships were seen for all variables except step time variability in women for whom the associations became progressively stronger with age. Our results suggest gait speed may be an intermediate in the pathway between age and step time and DST variability. Further research is needed into the factors responsible for the increased gait variability seen with advancing age.

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Gait variability among healthy adults: low and high stride-to-stride variability are both a reflection of gait stability

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INTRODUCTION: It has been suggested that stride-to-stride variability (STV) is a reflection of gait instability [1]. However, both low and high STV have been shown in fallers as well as non-fallers; therefore, the interpretation of STV of spatio-temporal gait parameters remains difficult [2]. Thus, we sought to characterize and compare STV of spatial and temporal stride parameters among young and older healthy adults, and to determine the extent to which opposite results in STV could provide similar implications in terms of gait stability.

METHODS: Mean values of coefficients of variation of spatio-temporal gait parameters were collected from 30 young adults (14 men and 16 women; mean age 28.1 ± 6.0 years) and 33 older adults (2 men and 31 women; mean age 74.4 ± 7.1 years) while walking at self-chosen normal walking speed over a GAITRite® System.

RESULTS: An age-related increase in STV was only observed with stride width ($p = 0.012$), whereas increased stride length and stance time variability in older adults were related to decreased walking speed ($p = 0.006$ and $p = 0.018$). In addition, both low and high STV were found in both groups of subjects and the highest value was observed for stride width ($p < 0.001$).

CONCLUSIONS: The two main implications of the present results are that decreased walking speed should be taken into account while exploring age-related effects on gait variability, and that both low and high spatio-temporal STV may reflect gait stability in healthy adults.

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Sensory and motor changes due to aging and the effects on postural control

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INTRODUCTION: With aging, individuals exhibit several structural, functional, and behavioral changes. Postural control performance depends on the integrity of both sensory and motor systems; deterioration of these systems due to the aging influences postural control performance of older adults. However, it is still unclear which sensory and motor functional changes are due to aging *per se*, neither the relationship between these changes and the performance of postural control in older adults. Therefore, the purpose of this study was to examine sensory and motor changes and the relationship between changes in these systems and postural control in older adults.

METHODS: Twenty older (68.9±3.7 years) (OA) and 20 young adults (21.9±2.1 years) (YA) were submitted to sensory, motor, and postural control assessments. Sensory assessment involved visual (acuity and contrast sensitivity) and somatosensory tests (foot tactile sensitivity and ankle and knee threshold of passive motion detection). Motor assessments involved joint torque and muscular activity latency after displacement of support surface. Postural control assessments involved magnitude of body oscillation in semi-tandem stance, resolution of conflicting sensory integration due to discrete movement of a moving room, and the coupling between visual information and body sway in periodic, complex periodic, and non-periodic moving room movement.

RESULTS: Older adult participants showed lower performance than YA in all sensory and motor assessments. Regarding postural control, OA participants displayed larger mean sway amplitude in semi-tandem stance and were more influenced by the moving room manipulation in the more complex conditions (complex periodic and non-periodic) than YA, besides exhibiting a stronger coupling between visual information and body sway in these conditions. Multiple linear regression analyses indicated that the sensitivity to passive joint motion contributed the most to the variance in mean sway amplitude during semi-tandem stance, complex periodic, and non-periodic conditions and to the variance in gain under these latter conditions.

CONCLUSIONS: Structural and physiological changes due to aging *per se* lead to decreasing of sensory and motor system performance. Detection of movement around the ankle contributes the most to larger body sway in upright stance and in visual manipulation conditions in older adults.

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Relationship between ankle range of motion and postural stability in elderly women

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INTRODUCTION: Increased incidence of falling in aging has been associated with over-reliance on the hip strategy for counteracting even small perturbation amplitudes. This in turn, is attributed to the impaired capacity of the ankle muscles to develop the required counteracting torques at the joint [1]. A reduced range of ankle joint motion has also been reported [2]; nevertheless, the impact of this age-induced constraint on postural stability is not well explored. The present study investigated the relationship between ankle Range of Motion (RoM) and postural stability in elderly women performing static leaning and dynamic swaying in the saggital plane. It was hypothesized that a reduced ankle RoM could be related to greater hip involvement during performance of static and dynamic inverted pendulum pivoting tasks.

METHODS: Fifty healthy, community dwelling elderly women (78±2.3years, 87.5±9.64kg) performed a) a static leaning test that involved slowly leaning forward and backward until reaching maximum leaning angle, b) a dynamic swaying test involving maximal whole body oscillations performed continuously for 20 s, c) an active ankle joint RoM measurement test in the Dorsiflexion (DF) and Plantarflexion (PF) direction. Ankle RoM and postural motion were recorded using 4 electromagnetic tracking sensors (Flock of Birds,100 Hz) attached to the 5th metatarsal bone, calcaneous bone, head of fibula and lower shaft of the shank for the RoM test and the forehead, 7th cervical (C7, trunk), 1st sacral (S1, pelvis) vertebrae and lower shaft of the shank for the postural tests. A dual force platform (Bertec Balance Plate 6501) was used to measure centre of pressure displacement during the postural tests. Hip involvement was quantified by calculating the C7-S1 marker angular rotation difference for static leaning and the C7-S1 marker Cross Correlation Function (CCF) for dynamic swaying. The relationship between ankle RoM and postural performance was analyzed using bivariate correlation (Pearson product moment) and linear regression analysis.

RESULTS: During static leaning, the degree of hip involvement was positively correlated with trunk inclination amplitude (forward: $R = 0.514$, $p<0.001$, backward: $R = 0.672$, $p<0.01$). During leaning backwards, ankle PF RoM was moderately, yet significantly associated with shank rotation amplitude ($R = 0.299$, $p<0.05$). None of the other postural variables showed a significant relationship to either ankle DF or PF RoM. During dynamic swaying in the saggital plane, ankle DF RoM showed a positive relationship to C7-S1 CCF index ($R = 0.307$, $p<0.05$) whereas the PF RoM was significantly correlated with shank rotation amplitude ($R=0.243$, $p<0.05$).

CONCLUSIONS: A modest relationship between ankle joint RoM and postural variables during static leaning and dynamic swaying was shown by the present study. The hypothesis according to which an age-induced reduction in the ankle RoM could be implicated for the greater hip involvement during performance of inverted pivoting tasks was not confirmed. Based on these findings, it could be inferred that during inverted pendulum pivoting, older adults do not reach to stability limits that would allow involvement of the passive joint structures but rather, they modulate ankle joint stiffness through active control mechanisms. For this reason, other age-limiting factors such as the reduced ability to maximally activate the muscles seem to have a more critical role than ankle RoM for controlling inverted pivoting using the ankle strategy.

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Coordination of walking and hand motor control in the elderly

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INTRODUCTION: When walking while carrying an object, young adults anticipate changes in inertial forces resulting from acceleration and deceleration of gait, and adjust their grip (normal) forces accordingly to maintain object stability. This coordination suggests a common internal representation for posture and fine motor control. The observation that anticipatory grasp control is maintained when gait is perturbed (e.g., stepping over an obstacle) indicates that attentional shifts necessary to alter regular walking do not impact anticipatory grasp control in young adults. However, it is unknown whether the coordination of gait and grasp control is preserved in the elderly. Moreover, attentional demands associated with gait modifications may use a greater amount of attentional capacities available to the elderly, resulting in decrements of the secondary task such as anticipatory grasp control. Hence, the purpose of this study was to investigate the coordination of walking and concurrent object transport in the elderly. To assess the influence of varying levels of attention allocated for gait modification, subjects were required to alter their gait cycle in a variety of ways.

METHODS: Eight healthy elderly (mean 68.8 years) and 8 young subjects (mean 26.6 years) participated in the study. Exclusion criteria for the elderly subjects were: Mini Mental State Exam Score < 24, Timed-Get-Up-Go > 15s, and 2-Point Discrimination < 5 mm. All subjects carried an object in their right hand using a precision grip during regular unperturbed walking (self-paced and fast) and during perturbed walking that required a change in step length (short and long step), and stepping over an obstacle.

RESULTS: The coordination of grip and inertial forces in the elderly was similar to that of the young subjects during unperturbed walking and when changes in step-length were required. However, the time lags of the grip force adjustments relative to gait-induced inertial force changes were increased in the elderly when stepping over an obstacle. Kinematic analyses showed that the increased time lag was not related to gait velocities, the amount of object dampening, or the foot clearance patterns since these variables were similar in both groups.

CONCLUSIONS: Healthy elderly are able to coordinate grasp control with locomotion. Only when attentional demands associated with the locomotor task increase, deterioration in fine motor control emerges. The changes in anticipatory grasp control during obstacle crossing can not be explained by differences in kinematics. We suggest that limitations in attentional resources result in the deterioration of anticipatory grasp control in the elderly when performance on a locomotor task must be prioritized.

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Acceptance and efficacy of the Nintendo Wii fit as a balance training activity for older people at risk of falls

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INTRODUCTION: The Wii is an innovative games system that allows people to train their balance and strength [1]. The Wii has had a promising uptake by physiotherapists and rehabilitation teams although robust studies on the Wii are rare [2, 3].

METHODS: A questionnaire was conducted with participants of balance and falls prevention classes to ascertain their acceptance of the technology and the perceived benefit. In addition current clients of a falls prevention class were evaluated using the Wii Fit Balance board for centre of gravity before and after 10 minutes of balance training.

RESULTS: Participants reported a high level of acceptance and enjoyment of the new technology. Participants found the Wii fit to be useful helping them reach their rehabilitation goals. Centre of balance was improved immediately after training in each client although these results were not significant.

CONCLUSIONS: The Wii fit can be a useful addition to balance and falls rehabilitation programs for older adults. More robust research is required to ascertain the training effects of the Wii and the most appropriate exercises and length of time required for an improvement in balance to occur.

Fig.1 Example of Wii Fit balance activity

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Stepping parameters measured using Dance Revolution style games reveal significant differences between older and younger adults

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INTRODUCTION: The ability to make timely and appropriately directed steps underpins our ability to maintain balance, move unaided through the environment as well as counter potentially-destabilising events (such as slips and trips) and avoid obstacles [1]. Recent studies suggest that stepping ability is significantly impaired in older versus younger adults, particularly in those older adults at higher risk for falls [2]. There is also evidence that stepping ability can be significantly improved in older adults via repetitive training of stepping responses [3]. However, repetitive practice can be boring and is likely to have poor adherence. One possible method to increase adherence involves the use of video games such as Dance Revolution (DDR). We have developed an age-appropriate version of this game that can also acquire data on stepping ability.

METHODS: Younger (20-30yrs) and older (70-80yrs) participants performed DDR games where a lightweight USB "dance mat" was connected to a computer running the game software. Participants were required to step onto the appropriate target arrow on the dance pad when a vertically drifting arrow on the computer screen overlapped with a target arrow at the top of the screen. Performance on the task was characterised by a measure of step-target asynchrony, computed from the ratio of vertical pixel difference between drifting and target arrows at the time that a step is registered to the velocity of the drifting arrow. Positive asynchrony values indicate that the step occurred before the drifting arrow was co-aligned with the target arrow, negative values indicate that a step was made too late. Graded feedback was provided to the participant based on asynchrony values as well as a cumulative game score. We systematically varied parameters of stepping such as arrow drift speed, cadence and step pattern complexity.

RESULTS: Example data are shown in the figure where average step target asynchrony (±95% CI) is plotted as a function of arrow drift speed (in degrees of visual angle). Older adults tended to step too early for slowly drifting arrows and asynchrony scores were significantly linearly related to arrow drift speed (Adj. R^2 =0.94). Best performance (smallest asynchrony) occurred for drift speeds around 10.5deg/sec. Younger adults tended to step onto target arrows "on-time" for a wider range of drift speeds. Other parameters of stepping showed similar differences between older and younger adults.

CONCLUSIONS: Our modified DDR game suggests a novel way of engaging older adults with repetitive step training that could be deployed into the home environment. We are able to acquire characteristics of stepping performance that reflect age differences. Our data indicate that slower drift rates do not necessarily lead to better performance for older adults in DDR style games.

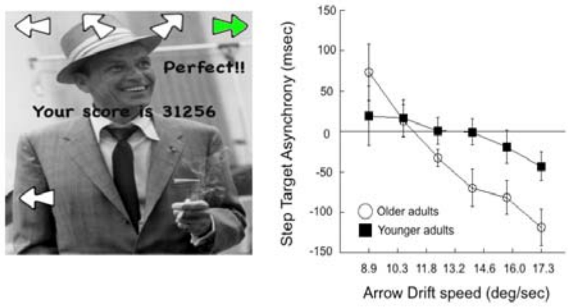

Fig.1 Our DDR game (left) and mean step asynchrony (right) scores.

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The effects of manipulating stair edge visibility on foot placement and balance control of young, low-risk and high-risk older adults during stair descent

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INTRODUCTION: Reduction of ambient light [1] or blurring vision [2] during stair descent results in lower foot clearance and reduced postural stability. The present study investigates how the visibility of stair edges and risk of falling affects foot positioning, foot clearance and Centre of Mass (COM) behaviour in young and older adults.

METHODS: Young (n=15) and older adults (n=15) descended a 5-step wooden staircase under two visual conditions. Stair edges were either covered with a black edge strip (high contrast) or not covered (low contrast). Older adults were subdivided into two fall risk groups: low risk of falling (n=7) and high risk of falling (n=8). To exclude walking speed as confounding variable, walking speed in the young group was matched to the older group. Foot clearance, foot placement on the stairs (Fig.1), COM velocity and acceleration at initial contact at the stairs were compared for age-related differences and the influence of fall risk. Data analysis included two 2x2 mixed ANOVAs comparing young vs. older age group and high- vs. low-risk older adults.

RESULTS: Walking speed did not differ between age groups (p=.626), but COM acceleration in the forward direction was greater for older adults than young adults (p=.010). Young adults placed a smaller proportion of their feet onto the stairs (p=.002), shown by the larger overlap of the foot over the stair edge (19% of the foot for young vs. 9% of the foot for older adults) and demonstrated a larger horizontal foot clearance than older adults (7.6cm for young vs. 6.5cm for older adults) (p=.037). We found an interaction between age and stair edge contrast for the vertical foot clearance. Only young adults significantly increased the vertical foot clearance when stair edge contrast was high (p=.006). High-risk older adults showed a smaller vertical (p=.001) and horizontal (p<.001) foot clearance than low-risk older adults. The effect of using high-contrast stair edges was to decrease horizontal foot clearance in low-risk older adults but to increase horizontal foot clearance in high-risk older adults.

CONCLUSIONS: When walking speed was matched, older adults used a larger base of support for the COM than young adults, but showed an increased COM acceleration in the forward direction, that may add to instability during stair descent. Using high contrast stair edges appears to be more beneficial to young adults than older adults since the vertical foot clearance is only significantly increased in this age group. However, using high contrast stair edges has a positive effect on performance of older adults with a higher risk of falling as they showed greater horizontal foot clearance and are therefore less likely to catch the heel on the stairs.

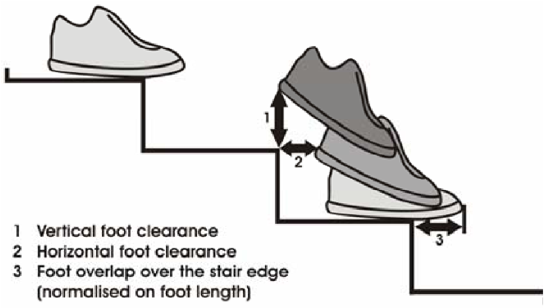

Fig.1: Minimum foot clearances were calculated for the stair during swing phase, foot overlap is the shortest distance between toe-cap and stair edge during stance phase.

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Correction of presbyopia using a monovision approach may compromise gait safety

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INTRODUCTION: The reduction in focusing ability that occurs with age and leads to most people needing reading glasses, bifocals or progressive addition lenses at the age of 40-50 years is called presbyopia. An increasingly common and convenient means to correct presbyopia is to wear one contact lens corrected for distance vision and the other for near vision. This is called a monovision correction and has the disadvantage of disrupting stereoacuity (depth perception) and thus, potentially reducing safety during adaptive gait. We have previously shown that a monovision correction given to older adults not familiar with such a correction led to increased lead-limb toe clearance when stepping over an obstacle or onto a step (Vale et al., 2008a,b). This increase in lead-limb toe clearance was interpreted as a 'safety' strategy due to uncertainties regarding the position and/or height of the raised surface or obstacle. In the present study we investigate how older adults who had habituated to wearing a monovision correction over several years (mean 5.4±2.6 years) negotiate a raised surface in their travel path, compared to when the same patients perform the task using fully corrected distance vision lenses in each eye.

METHODS: Eleven healthy older adults (mean age 53.5±4.6 yrs) walked up to and on to a new level (152mm in height) under monovision correction or distance vision correction conditions. Our analysis focused on foot positioning and lead-limb toe clearance parameters when approaching and stepping onto the raised surface. **RESULTS:** The monovision correction significantly impaired stereoacuity from 1.22 (SD 0.09) to 1.94 (0.14) log seconds of arc, compared to distance vision correction conditions (*p*<0.001). Trail-foot position before the raised surface (mono, 316mm, distance, 394mm, p=0.041) and toe clearance were significantly reduced (p<0.00001, Fig1A), and toe clearance within-in subject variability significantly increased (p<0.0001, by 38%, Fig 1B) under monovision correction compared to distance vision correction conditions.

CONCLUSIONS: Findings indicate that older adults wearing a monovision correction had significantly reduced stereoacuity compared to distance vision correction and this was associated with increased toe clearance variability and significantly reduced toe clearance when negotiating a raised surface. This result highlights that margins of safety were reduced and risk of hitting the raised surface was increased under habituated monovision correction conditions. These findings suggest that caution should be taken when considering monovision correction for individuals who are considered to be at a higher risk of falling.

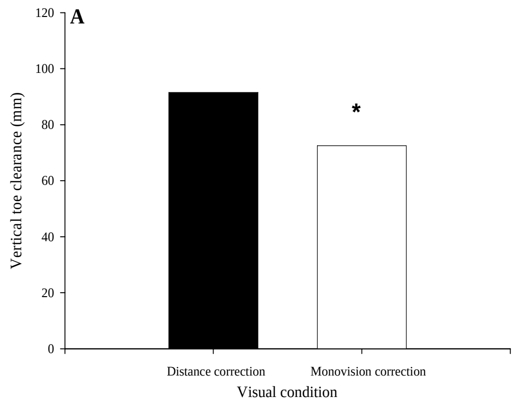

Fig.1. A) Mean toe clearance, and B) toe clearance with-in subject variability

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Ageing involves wider spectral bandwidth and greater amplitude of EMG signals during walking

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INTRODUCTION: Electromyographic signals (EMG) reflect the relationship between signals coming from the Central Nervous System and peripheral pathways, and muscle activations. Spectral features of EMG have been shown to be correlated with conduction velocity through the nervous system [1] and recruitment of motor units [2]. Ageing affects neural control of muscles both in term of descending signals and peripheral afferences. This study was aimed at characterising the age-related modifications of EMG signals responsible for neural control during locomotion.

METHODS: Seven young (27.3 ± 4.9 years) and seven elderly (69.0 ± 1.4 years) healthy subjects have been enrolled. Muscle activity of twelve ipsilateral leg muscles (Tibialis Anterior, TA , Gastrocnemius Lateralis, GL, Peroneus Longus, PERL, Vastus Medialis, VM, Rectus Femoris, RF, Biceps Femoris, BF, Semitendinosus, ST, Tensor Fascia Latae, TFL, Adductor Longus, ADD, Gluteus Maximus GM, Soleus, SOL, Gluteus medius, Gmed) have been recorded by using surface electrodes (sample rate 1500 Hz). Subjects were asked to walk at 6 cadences (from 40 to 140 steps/min) beaten by a metronome. Cadence was adopted as metric to make data comparable between the groups [3]. Firstly, for each gait cycle, EMG signals were pre-processed (rectification, filtering, amplitude normalisation). Following, Coefficient of Variation (CV) and Centroidal Frequency (CF) of each signal within the whole gait cycle, and mean of the normalised signal (MS) during five phases of the gait cycle (0-10%, 10-30%, 30-60%, 60-73% and 87-100% of the gait cycle) have been computed.

RESULTS: CVs of young were higher than elderly subjects for almost all muscle groups at all cadences. CFs in elders were always higher than in young. Concerning the amplitude of the EMG signals, only during the middle stance, muscle activations in elders were slightly higher than in young. In the other analysed phases, signals amplitudes were comparable between groups (see Figure 1).

CONCLUSIONS: Elders exhibited more consistent EMG patterns than young subjects, in conjunction with an increased spectral bandwidth. Moreover, in older adults, during the middle stance, muscles were activated with greater amplitude. This would suggest that physiological modifications of the neuromuscular system, due to ageing, could be reflected in the EMG signals. In particular, ageing would involve a wider recruitment of remaining muscle fibers and a greater dispersion of the descending signals due to the loss of synchronization of Motoneuronal activity.

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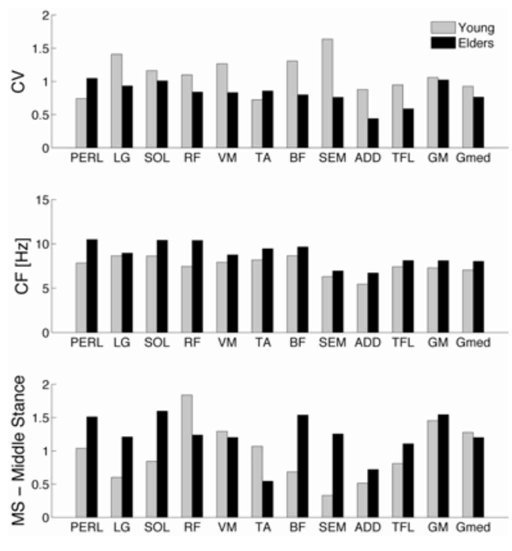

Fig. 2 Average of the features during walking at 100 steps/min

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Older adults can selectively use rotational optic flow cues to guide heading direction while walking

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INTRODUCTION: Optic flow is a well-known perceptual cue in the determination of heading direction. Recently, it has been shown that older adults are less able to head straight in a virtual environment than young adults when exposed to translational flows while walking [1]. However psychophysical evidence suggests that older adults have similar discrimination abilities as younger subjects in detecting radial flows [2]. The purpose of this study was twofold: first, to investigate the ability of healthy older adults to use rotational flow for heading while walking; and second, to examine the ability of older adults to re-weight sensory information when visual information on rotational flows were to be ignored while walking straight.

METHODS: Five young adults (26.5 ±3.4 years) and 4 healthy older adults (76.8 ±1.8 years) have been recruited and included in the preliminary analysis while another 10 subjects in each group will be recruited. Subjects were evaluated while walking overground for 5m and wearing a helmet-mounted display (HMD; NVisor) unit. The scene presented in the HMD was of a large room 4m x 10m with vertical and horizontal cues but no obstructions. Kinematic data of the head and whole body were recorded using a Vicon motion capture system. Movements of the head were tracked in real-time via three markers placed on the HMD and fed to the CAREN-2 (MOTEK) system, allowing for the real-time head movements to be synchronized and the corresponding optic flow displayed in the HMD. Subjects were instructed to either: (1) use optic flow information and walk straight with respect to the scene in the HMD (virtual environment: VE) or (2) ignore visual information and walk straight with respect to the physical environment (PE). In both conditions, the focus of expansion was randomly rotated by 40° to the left or right or remaining neutral (0°) after 1.5 m of walking.

RESULTS: In the presence of rotational flows, older adults adjusted their locomotor behaviour similar to younger adults. When instructed to walk straight in the VE (using optic flow), both younger and older subjects rotated their centre of mass (CoM) away from the direction of flow (Fig 1A). When instructed to walk straight in the PE (ignoring optic flow), both older and younger adults are able to suppress the visual information, resulting in a straight CoM trajectory regardless of the FOE rotation (Fig 1B).

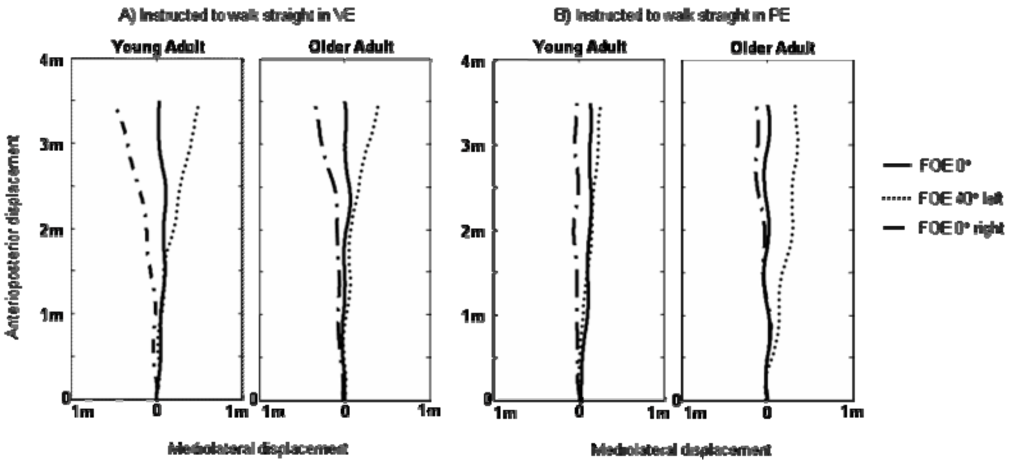

Fig.1 Representative data from one young adult and one older adult when instructed to walk straight in the virtual environment (A) or the physical environment (B).

CONCLUSIONS: The ability to interpret and use rotational flow patterns is maintained with aging. However, preliminary analyses suggest that there may be differences in terms of the magnitude of responses.

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Planar Covariance during Weighted Level Ground Walking and Obstacle Clearance Tasks

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INTRODUCTION: During walking the segment elevation angles of the lower limb have been found to co-vary within a plane across a wide variety of locomotor tasks including walking at different speeds, walking up inclined surfaces, walking upstairs and hopping [1-4]. Coordination of segmental orientation during locomotion requires a precise interaction between various neural centres, the musculo-skeletal system and the environment. The goal of this study was to assess the impact on intersegmental coordination when alterations are made to the inertial properties of the musculo-skeletal system and when environmental constraints necessitate a voluntary modification to the normal locomotor pattern.

METHODS: Kinematic data were collected on 8 young adults (4M, 4F, mean age = 23.8 ± 1.91 yrs, mean mass = 68.7 ± 6.09kg, mean height = 171.6 ± 5.57cm) during level ground walking and obstacle clearance tasks. Subjects participated in six randomized blocks containing 10 level walking trials and 10 trials where they had to step over a 20 cm obstacle. In three of the blocks additional mass (0.5, 1, or 2 kg) was added to the shank. Segment elevation angles were determined over a complete stride. Principal Component Analysis was used to determine the amount of co-variation of the segment elevation angles, as described by Borghese et al [1], and a planarity index (PI) was calculated for each condition [2]. A repeated-measures two-way ANOVA was carried out on relevant variables in order to determine statistical significance.

RESULTS: Adding mass to the limb had no effect on the PI, or plane orientation in both the level walking and obstacle clearance conditions. However, stepping over an obstacle resulted in a significant decrease of the PI ($p = 0.0015$) and altered plane orientation ($p = 0.0129$) when compared to the level walking trials.

CONCLUSIONS: The major change in both PI and plane orientation shows that the participants employed a different walking strategy when stepping over the obstacle when compared to level walking. This was most significant during the swing phase where deviations from the covariance plane were most substantial. Since adding mass to the shank did not cause changes in the PI or plane orientation for the walking or obstacle clearance conditions, it is evident that the CNS was robust in adapting to altered inertial properties. However, adding this mass may have produced more substantial changes if a greater magnitude of mass was used or if the subjects walked without previously adapting to the additional mass prior to the data collection [5].

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How long does it take to adjust steps after an unexpected perturbation during running?

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INTRODUCTION: The mechanism of running can be modelled as a simple spring-mass system bouncing on the ground, with a single spring representing the runner's leg and a point mass equivalent to body mass. When the conditions of running are modified, for example by changing surface stiffness [1] or running barefoot compared to shod [2], it has been shown that runners adjusted their leg stiffness. We applied an unexpected dorsoflexion to the ankle just before the foot contact during running. We observed some immediate biomechanical adjustments, including a decreased leg stiffness and a decreased and delayed foot-slap (unpublished results). We are now interested in quantifying the long-lasting effect of the perturbation: Is the next step still affected by?

METHODS: Four male subjects (27.3 ± 2.0 years, 77.4 ± 12.3 kg, 182.6 ± 2.6 cm) ran at 2.8 $m.s^{-1}$ on a treadmill. A new experimental portable device, inspired by that of Andersen and Sinkjær [3], was designed to deliver a well-defined perturbation to the right ankle joint at a precise moment while the subject is running on a treadmill. This apparatus consists of two carbon fibre shells which hold the foot and the lower leg. These shells are linked by a hinged joint pivoting at the centre of rotation of the ankle and allowing only dorso-plantar movements. A clutch connected to a servomotor by a cable is capable of flexing the foot at a maximal speed of 600$deg.s^{-1}$ and a maximal torque of 300 N.m. This clutch can be activated at any predetermined moment of the stride. The whole device weights less than 1 kg. During the experiments, the ground reaction forces were measured by 4 force transducers mounted under the treadmill (1kHz sampling). The angular position of the ankle was measured with an optical encoder incorporated in the ankle device (1kHz sampling). We unexpectedly provoked a dorsoflexion of the right ankle 42 ± 14 ms (n = 88) before the right foot contact during running and provoked an accented dorsoflexion of the right ankle at the time of foot contact. Here we analyze the effects on the following left step.

RESULTS: At the time of foot contact, the right ankle is 5.5 ± 2.3 deg ($p<0.0001$) more in dorsoflexion. This perturbation affects the following left step by a significant increase of the leg stiffness in 2 of the 4 subjects, but with an unmodified foot slap in amplitude and timing. The left step period as well as the left step contact period were unmodified.

CONCLUSIONS: We have already shown (unpublished results) that an unexpected perturbation of the right ankle just before the right foot contact during running affects that right step (in our 4 subjects), including a decreased leg stiffness with a decrease and a delay of the foot-slap, even if the right step period was not modified. Here, we show that this also affects the following left step but in a lesser extend. We observe an increased leg stiffness only in 2 of the 4 subjects and no change in the foot-slap or in the left step period. In conclusion there seems to be a progressive return to normal running.

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Patterns of elevation angle planar covariation during obstacle clearance

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INTRODUCTION: During gait [1,2] and other locomotor tasks [3], if lower limb (foot, leg, and thigh) segment elevation angles are plotted, they tend to create a plane in 3D space which is termed the planar law of intersegmental coordination. The current study examined changes in segment elevation angles when stepping over obstacles of various configurations. Preliminary, ongoing, results are presented here.

METHODS: To date, four healthy young adults stepped over obstacles of 9 configurations in which obstacle height (0%, 10%, and 20% of leg length) and width (~0%, 10%, and 20% of step length) were manipulated. The 0% height condition consisted on placing paper with the required width on the walkway for the participant to clear. The ~0% width was a thin (3 cm) obstacle. The 0% height/0% width condition had no obstacle present. Full body 3D kinematic data (Optotrak 3020) was collected and elevation angles of the foot, shank, and thigh in the sagittal plane were calculated. For each limb within each trial, a principal component analysis was applied to limb segment trajectories to determine planarity (percentage of total variation accounted for by the first 2 components) and plane orientation (eigenvector corresponding to the direction cosine between the 3rd component and the thigh axis [2]). A three-way ANOVA was used to determine preliminary differences between obstacle height, obstacle width, and crossing limb (leading, trailing).

RESULTS: Planarity remained high (98.3 – 99.6%, Fig 1A&B) in all conditions although it was significantly higher in the trailing limb ($p < 0.001$) and during 0% obstacle height conditions ($p < 0.001$). The percent variance accounted for by the 1st principal component was significantly higher ($p < 0.001$) during 0% obstacle height conditions. The eigenvector indicating plane orientation decreased significantly as obstacle width increased ($p < 0.009$), as obstacle height increased ($p < 0.001$), and was significantly higher in the trail limb ($p < 0.001$).

CONCLUSIONS: The planar law of intersegmental coordination appears to hold when stepping over obstacles of different configurations although a re-weighting of the principal components occurs when stepping over higher obstacles. This suggests coordination of elevation angles when stepping over obstacles is achieved by different weightings of 2 primary patterns. These results also show that the orientation of the covariance plane is not consistent when stepping over different obstacles (and also differs between limbs) which may be related to phase changes between the thigh and leg segments as seen in curved walking [4].

ACKNOWLEDGEMENTS: Financial support provided by NSERC.

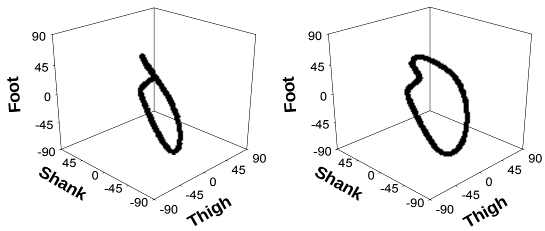

Fig 1: Representative segment elevation angles (degrees) for level walking (A) and lead limb obstacle clearance (B)

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Hierarchical synergic control of posture

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INTRODUCTION: The idea of hierarchical control of vertical posture is not new. We merge this idea with the notion of synergies defined as neural organizations that ensure patterns of co-variation of elemental variables with the purpose to stabilize a performance variable. At each level of the hypothetical control hierarchy, a few-to-many mapping takes place: The input defines a performance variable that this level is expected to produce while the output represents elemental variables that are coordinated to produce the desired input. This structure allows to use sets of elemental variables to produce different performance variables simultaneously with minimal interference.

METHODS: In recent studies, we explored the hypothetical hierarchy at two levels. First, we studied changes in the composition of muscle modes (M-modes, viewed as performance variables) with such factors as complexity of postural task, practice of challenging motor tasks, and specific variable that the subject is instructed to produce accurately. Second, we explored patterns of M-mode co-variation that helped stabilize such mechanical variables as coordinate of the center of pressure, shear force, moment of force about the vertical body axis, and moment of force in the ankle joint.

RESULTS: We have shown that individual muscle activations (elemental variables at this level) can form different M-modes in tasks of different complexity. Practice in challenging conditions could lead to changes in the M-mode composition. In asymmetrical tasks that required the production of a pattern of moment of force about the vertical axis of the body, subjects showed idiosyncratic M-modes that were also task-dependent. At the higher level of the hierarchy, the involvement of individual M-modes was shown to co-vary across trials in a way that stabilized such performance variables as coordinate of the center of pressure, shear force, and moment of force about the vertical body axis. Two variables, the center of pressure coordinate and the shear force magnitude, both in the anterior-posterior direction, could be stabilized simultaneously by co-varied adjustments of the three M-modes.

CONCLUSIONS: The suggested framework allows to link patterns of muscle activation in postural tasks to stabilization of potentially important mechanical variables. Multi-M-mode synergies allow performing secondary tasks, handling new constraints, and dealing with perturbations. The principle of superposition has been confirmed for multi-muscle stabilization of two variables at the same time. These results may be interpreted within the framework of the equilibrium-point hypothesis of motor control. This method of control uses thresholds of muscle activation as control variables and operates with reference body configurations. Deviations of an actual body configuration from the reference one leads to activation of groups of muscles that are naturally united to stabilize performance variables defined by the change in the reference body configuration.

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Contributions of the upper limb movements on body equilibrium during the process of learning a dynamic balancing task

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INTRODUCTION: This study investigated the influence of upper limb movements on body equilibrium while learning a continuous dynamic balancing task. Coordinated arm movements may help stabilize the falling motion of the body by acting as a counterweight [1], generating reaction moments of force [2], and by altering the body's moment of inertia [3]. Thus, it is predicted that the upper limb would be utilized to help stabilize balance. Furthermore, considering that new and more task-specific joint couplings emerge during learning [4], it is believed that constraining upper limb movement thereafter may be detrimental to postural stability.

METHODS: Motor performance was examined during ACQUISITION, RETENTION, and TRANSFER phases of a dynamic balance task (standing on a stabilometer). Twenty-two healthy young adults were divided randomly in two groups: one initially performing the balance task with arms free (FREE condition), the other learning the task without the use of their arms (CONSTRAINED condition). Both groups were tested for retention of the task one day and one week later (RETENTION phase), using the same initial arm condition. Transfer of the learning on the motor task was tested at these same times by switching the arm condition (TRANSFER phase; FREE to CONSTRAINED arm condition or vice versa). The ACQUISITION, RETENTION, and TRANSFER phases consisted of four blocks of 15 trials, 5 trials and one block of 15 trials, respectively. Balance duration on the stabilometer (up to the maximum trial length of 20 s), and trunk, upper and lower limb movements were recorded. These results were analysed using a mixed model ANOVA, with blocks of 5-trials during acquisition, retention and transfer (20 blocks of 5-trials total) as within factors and Group as a between factor (α=0.05).

RESULTS: Both groups increased the duration in which they could maintain balance between the 1st and 12th block of the acquisition trials (increase in balance duration: $\Delta FREE_{1-12}$=3.2s; $\Delta CONSTRAINED_{1-12}$=3.9s). This increased balance duration carried over in the retention trials (p's>0.05). A significant interaction between groups and trial block ($p<0.001$) indicated that the balance time was increased in the transfer from the CONSTRAINED (16.4 s) to the FREE (17.7 s) condition ($p<0.01$) whereas no change was observed for the FREE (17.1 s) to CONSTRAINED (16.8 s) group ($p=0.25$).

CONCLUSIONS: These preliminary observations suggest that the availability of the upper limb made no difference in learning to maintain balance on the stabilometer. However, balance performance was improved when subjects were free to use their arms in the transfer trials after learning the task without use of their arms. Analysis of segment motion will determine if both groups learned to use their arms in a similar fashion to control segment and whole-body motion.

ACKNOWLEDGEMENTS: Supported by NSERC.

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The influence of stride frequency and body-weight support on muscle coordination during weight-assisted treadmill locomotion

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INTRODUCTION: Partial body weight-supported treadmill training is a commonly used approach for the rehabilitation of patients with incomplete spinal cord injury. By providing repetitive rhythmic input to a patients legs, treadmill training provides the sensory feedback necessary to enhance neural output of a 'central pattern generator' for stepping movement. Treadmill training has also been shown to improve ambulatory capacity. Functional improvements have been associated with improved muscle activity patterns during gait.

METHODS: The purpose of this study was to identify the contribution of the level of body-weight support and stride frequency to the coordination patterns of the leg muscles. Eight healthy subjects were tested. They walked on a treadmill at a combination of weight-support (0, 20, 40, 60 and 100%), and stride frequencies (0.40, 0.49 and 0.57 Hz). Treadmill walking was performed with the assistance of the Lokomat robotic gait orthosis to constrain leg kinematics. Surface EMG was collected from the following nine muscles: tibialis anterior, medial and lateral gastrocnemius, soleus, vastus medialis and lateralis, rectus femoris, semitendinosus, and biceps femoris. Each condition was presented twice in randomized order, for a total of 30 trials (15 possible combinations of weight support and stride frequency). Data were recorded for 60 seconds for each condition. A foot-switch identified the time of foot-contact with the treadmill belt and was used to identify individual strides. The intensity of the EMG was calculated using wavelet analysis (that provides a measure of the power of the EMG signal) and formed into a 9 x 100 EMG grid for each stride (9 muscles x 100 time points within each stride). The principal components (PCs) were calculated for the EMG grids (a total of 5250 grids across all 8 subjects). The EMG grids describe the patterns of activity between the muscles, and their PCs identify the major features and differences in these patterns.

RESULTS: The results showed a general increase in the level of muscle activity with reductions in body-weight support coupled to greater quadriceps activity during stance. The stride frequency primarily influenced the pattern of coordination between the muscles: walking at the lower frequency resulted in greater activity in the ankle extensors and hamstrings during the stance phase.

CONCLUSIONS: The results indicate that both the selection of stride frequency as well as body weight support can influence the coordination patterns within the leg and may thus be an important determinant when selecting the appropriate training parameters during gait rehabilitation.

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The effect of visual perception on coordination of posture and arm movement during standing

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INTRODUCTION: Arm reaching during standing is limited by subjective perception of body stability. This perception is developed taking into account the visual perspective in which the environment is observed. This suggests that manipulation of visual perspective can alter subjective estimation of stability restraints and influence motor performance. To test this hypothesis we compared reaching for an object in a virtually generated environment that was presented using different visual perspectives with reaching while standing in a real-world environment.

METHODS: Eleven young healthy individuals performed forward and lateral reaches in the physical world and in the virtually generated environment. In the physical world, they were instructed to reach as far as possible with no specific target. In the virtual world, participants stood in front of a screen in which they saw a computer-generated model of their body in a courtyard surrounded by a semi-circular hedge topped with flowers (Fig.1). The image was presented randomly in one of five different perspectives ranging from looking from directly behind (0º), to looking down from almost straight overhead (90º). Participants were instructed to reach for the furthest flower without a loss of balance or taking a step. Movement kinematics were recorded and analyzed in terms of the end-point displacement, arm-postural coordination and displacement of the center of mass.

RESULTS: The results showed that participants reached a greater distance in the virtual world, particularly with visual perspectives of approximately 45 to 77.5º. Greater distance was achieved by increased involvement of the leg and trunk body segments, and decreased inter-segmental delay at the moment of movement initiation and termination.

CONCLUSIONS: Thus these visual perspectives can be recommended as optimal for designing virtual rehabilitation programs for balance and functional movement re-training, for virtual reality game development, in ergonomic design, and teleoperation training.

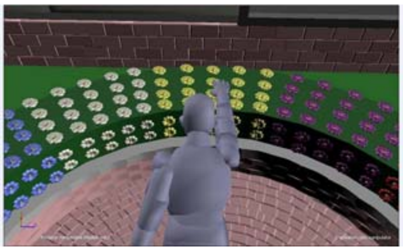

Fig. 1 Image of participant's avatar presented on the screen

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Ground reaction force coordination during split-belt treadmill walking

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INTRODUCTION: Few studies have investigated how the gait pattern of healthy adults is modified by walking on a split-belt treadmill at different asymmetry ratios (AR) (i.e. [fast belt speed - slow belt speed] / fast belt speed). In fact, most of them have studied the spatial-temporal gait modifications [1,2] using or not the ground reaction forces (GRF) [3] and only one investigated lower limb muscular activity modifications [4]. No studies have reported on the GRF modifications during split-belt walking despite its relevance when analysing postural control during gait using inverse dynamics methods. The purpose of this study was thus to analyse the variation of GRF at different AR and at different reference speeds (RS).

METHODS: Seventeen (N=17) healthy adults were asked to walk on a split-belt treadmill and completed 18 conditions. The ipsilateral leg (i.e. the dominant leg) corresponded to the fast belt working which was fixed at three RS (0.5m/s, 1m/s, and self-comfortable speed (SCS): 1.42 m/s). For each RS value, the speed of the slow belt which corresponds to the controlateral leg was varied at six RS coefficients: RS, RS*0.9, RS*0.8, RS*0.7, RS*0.6, and RS*0.5. The RS as well as the slow belt coefficient orders were randomized. The GRF data were collected using two Kistler force platforms. Five parameters were selected as dependant parameters. The medial, posterior and anterior GRF peaks, as well as the first and second vertical peaks. The ten most repeatable gait cycles were kept for statistical analysis.

RESULTS: For SCS condition, all the parameters decreased significantly ($p<0.001$) for the controlateral leg when AR increased except the first vertical peak. For the ipsilateral limb even if the speed belt was kept constant, all the parameters decreased significantly ($p<0.007$) except the anterior force peak. This behaviour was identical when the imposed speed RS =1 m/s were analysed with the exception of the low RS =0.5 m/s. The timing of the controlateral (fast leg) was affected by the asymmetric conditions. In fact, the timing of the anterior, the posterior, and the second vertical peaks occurred significantly earlier during the gait cycle than during the symmetric condition.

CONCLUSION: Walking in an asymmetric environment modifies the GRF pattern in the slow leg. In fact, the anterior posterior and vertical forces in the controlateral limb are the most affected by AR. In the other hand, the fast leg reacts by generating anterior, posterior, and second vertical peaks earlier in gait cycle and reducing slightly the force magnitude. In our point of view these are new results which could explain the fact that the fast leg reduces significantly the occurrence of the second vertical force peaks and lesser the percentage of stance duration, and the opposite for the slow leg. This could have an implication for the development of therapeutic programs for deficient leg such as in hemiplegia.

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Foot dynamics and posture change during walking on inclines

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Introduction: During walking on a treadmill, forward (X-axis) and upward (Z-axis) foot dynamics follow characteristics patterns that maintain a pendular-type movement and a small toe clearance. It is also known that foot dynamics are determined by walking velocity and frequency of stepping. We questioned how foot dynamics along the X- and Z-axes and toe clearance were affected by walking on inclines and how the head and body changed orientation as a function of the inclination angle.

Methods: Foot, leg, trunk and head movements were monitored in three dimensions with a motion detecting system (Optotrak 3020) while 6 healthy subjects walked on linear treadmill on grades from -5 to +10 deg at velocities of 0.6, 0.9, 1.2, and 1.5 m/s.

Results: Foot dynamics were affected by not only walking velocity and step frequency also walking grades. Toe trajectories in spatial coordinates were markedly different. However, when the toe position was computed relative to the extrapolated height of the treadmill, the toe trajectory was not significantly different from that determined during level walking at all velocities. The average knee and trunk angles in space were re-oriented with grade so as to maintain an average spatially forward pointing head orientation.

Conclusions: The model indicates that grade angle is built into the velocity and step frequency control signals, which drive the active feedback control that determines the forward foot dynamics and the Z-axis stepping kinematics and dynamics. To compensate for maintaining the dynamics relatively invariant as a function of locomotion angle, the average orientation of the legs and body are re-oriented to maintain the average head tilt close to the spatial vertical for all grades. This model, therefore, forms the basis for understanding the maintenance of fixed gaze during bipedal navigation over uneven terrain.

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Multiple APAs during voluntary step initiation in healthy subjects

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Introduction: One of the most troubling symptoms of Parkinson's disease is "freezing of gait," which can be described as difficulty initiating or maintaining forward motion while walking. Freezing while attempting to initiate walking is often accompanied by repeated weight shifts between feet, as if multiple anticipatory postural adjustments (APAs) were being generated [1]. A similar pattern can be induced in healthy controls if they are forced to take a compensatory step to keep their balance while they wait for a cue to tell them which foot to step with [2]. This suggests that freezing of gait may be due to factors that are always present to some degree, which cross a threshold in patients with advanced Parkinson's disease and in certain situations. The aim of this study was to determine whether multiple APAs can also be elicited in healthy controls before voluntary stepping, and, if so, under what conditions. Hypotheses: (1) If multiple APAs are caused by difficulty selecting a stepping foot online (especially when a program to step with a preselected foot must be canceled), then an uninformative ready cue (precue) followed by a choice reaction time stepping task (CRT task) should elicit multiple APAs. (2) If multiple APAs are caused by difficulty linking the APA with the forward stepping program, then a delay between a ready cue and a go cue should induce multiple APAs, even when the stepping foot is known in advance as in a simple reaction time task (SRT task). (3) If multiple APAs are exacerbated by the subject's weight being forward, then trials with multiple APAs should exhibit more forward lean between the precue and the go cue than trials without multiple APAs. (4) If multiple APAs are related to freezing, they should delay stepping.

Methods: Seven healthy young controls were instructed to voluntarily take a step in response to a go cue. There were four conditions: (1) no precue/SRT; (2) no precue/CRT; (3) precue/SRT; (4) precue/CRT. Each subject completed four blocks of 20 trials in each condition, in counterbalanced order. The precue consisted of a very small pulse under both feet at once, 600 ms before the go cue. The go cue was a light appearing in front of one foot or the other, indicating which foot should step first. Weight shifts were measured by force plates under each foot.

Results: Multiple APAs were evident in 3%, 10%, 16%, and 21% of trials in the four respective conditions. Forward lean was evident in both precue conditions, but it was related to multiple APAs in the precue/SRT condition only. Time to step was consistently longer in trials with multiple APAs than in trials without multiple APAs.

Conclusions: Both the addition of a precue and the requirement of a choice increased the likelihood of multiple APAs, suggesting that the requirement to select a stepping foot online and the need to couple the APA to the step are both potential sources of freezing. The next experiment will test Parkinson's patients with freezing of gait with the same protocol. If Parkinson's patients have a deficit in online selection of stepping foot, they should show more multiple APAs than controls in CRT conditions, even when there is no precue. If a deficit in coupling between APAs and stepping programs is a cause of freezing, then patients should show more multiples than controls in the precue conditions. The long-term aim of these studies is to develop a protocol that can reliably elicit freezing of gait initiation so we can develop effective biofeedback tools for overcoming freezing.

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Age and falls history-related differences in the biomechanics of 360º pivot turns

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Introduction: Older adults who fall during turning are eight times more likely to experience a hip fracture than from a fall during walking in a straight line [1]. The ability to turn has been identified as an important task of daily living, and the evaluation of turning has been included in many clinical assessments to determine those at risk of falling [2-4]. Therefore, the comparison of turning biomechanics in fallers and non-fallers in the older population is essential if we are to understand the mechanisms underlying falls. The aims of this study were to compare time to turn, number of steps utilised to turn, and segmental reorientation onset in groups of young adults and older non-fallers, single fallers and multiple fallers during a 360º standing turn.

Methods: Fifteen young adults (age 25.7 ± 3.2 years), and older non-fallers (n = 15, age 70.7 ± 6.2 years), single fallers (n = 11, age 70.2 ± 6.1 years) and multiple fallers (n = 14, age 71.5 ± 6.9 years) participated in this study. Participants completed three 360º turn trials at their own speed, and the participants self-selected their turning direction to make the movement as natural as possible. A 14-camera Vicon M2 (624) system was used to collect 3-D marker trajectory data sampled at 60 Hz, and the head, thorax and pelvis segments were defined. Thoracic and pelvic onset latencies were calculated with respect to head rotation onset, and pelvic onset latency with respect to thoracic rotation onset was also calculated. Group differences were investigated using one-way ANOVA.

Results: The young adults completed the turn in significantly less time than the multiple fallers ($F = 3.636$, $p = 0.019$), and utilised significantly fewer steps to turn ($F = 3.693$, $p = 0.018$). All of the participant groups demonstrated head yaw as the first movement in the initiation of the 360º turn. There was a significant difference between groups for pelvic turn onset latency with respect to the thorax ($F = 5.968$, $p = 0.001$), post-hoc tests showed the multiple fallers to have significantly shorter latency between the thorax and the pelvis than all other groups.

Conclusions: The multiple fallers demonstrated a more en-bloc strategy for turning than the other groups characterized by a shorter latency between reorientation onset of the thorax and the pelvis at the initiation of the turn. Interestingly, en-bloc turning strategy of the thorax and pelvis has been previously observed in both stroke and Parkinson disease patients; patient groups who also are at increase risk of falling during turning. In combination these results suggest that studying the biomechanics of pivot turns is a useful tool for elucidating the mechanisms underlying falls and diagnosis of increased falls-risk.

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Eye movements trigger the release of whole body postural turning responses during walking in a virtual environment

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Introduction: It is well established that turning is normally achieved through a coordinated sequence of whole-body rotation starting with the eyes and head and followed by the body and feet [1, 2]. Recent evidence suggests that turning can be considered to be a whole-body gaze shift which is driven by the oculomotor control system within the CNS [3]. We have previously shown that participants walking in a virtual environment that visually simulates turning a corner show anticipatory coordinated eye and whole body responses in the direction of the turn that are similar to those observed during real turns [4]. We hypothesize that visually evoked gaze shifts in the turn direction result in release of a pre-programmed coordinated postural synergy. The aim of the current study was to test this hypothesis by studying the effect of constraining eye movements on visually evoked postural responses. We predicted that preventing anticipatory gaze shifts in the new travel direction would attenuate or abolish whole-body responses.

Methods: Six university graduate students (27.8 ± 5.0 years) participated in the study. Participants were asked to step in place at a self-selected comfortable pace while immersed in a virtual environment which simulated walking down a hallway and turning a corner. Three simulated walking speeds were used; normal (1.4m/s), double speed and half speed. In half of trials participants were required to maintain gaze direction on a static target placed in the middle of the viewing screen. Whole-body kinematics and gaze behaviour were recorded using a Vicon 512 motion analysis system an ASL 501 gaze tracking system respectively.

RESULTS: In support of our hypothesis, gaze fixation on a stationary target resulted in abolition of anticipatory postural responses (figure 1). Although reactive postural adjustments were still observed during gaze fixation trials these were significantly smaller in amplitude than trials in which gaze was unconstrained (figure 2).

CONCLUSIONS: These findings lend support to the notion that the oculomotor system plays a key role in the control of turning and locomotor direction change and suggest that the postural steering synergy is a robust, preprogrammed and largely automatic process that can be triggered by visually evoked gaze redirection.

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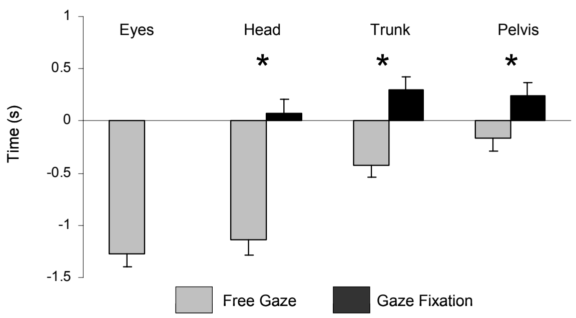

Fig.1 Timing of body segment reorientation

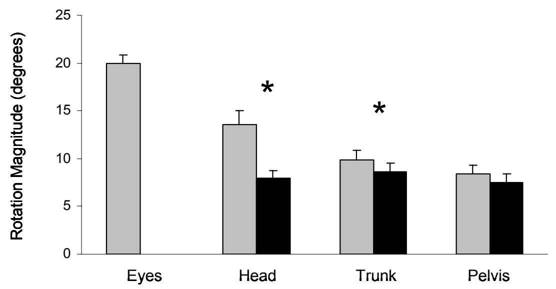

Fig. 2. Amplitude of segment with respect to onset of scene rotation rotation in scene turn direction

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Motor programming interaction in the sequence of sit-to-stand and walk.

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INTRODUCTION: It is known that the execution of a motor task is preceded by anticipatory postural adjustments (APAs) [1]. The APA parameters are adjusted so that the movement can be executed efficiently. They depend on the subject's postural kinetic capacity [2] and on the objective or constraints of the motor task [3]. Movement often involves several successive motor tasks where each of them is preceded by APAs. In the present study, we examined the interaction between two successive motor tasks of sit-to-stand and walking on their respective APAs.

METHODS: Twelve adults performed 3 movements: Sit-to-Stand (STS), Sit-to-Stand followed by Gait Initiation (STS-GI), and gait initiation (GI). Ground reaction force was recorded from a large force platform (0.9m x 1.80m, AMTI), then kinematics of centre of mass was calculated. The subject was instructed to vary the speed of the motors tasks between trials. More particularly, in STS-GI the subject was instructed to carry out spontaneous STS followed by spontaneous or fast GI, or fast STS followed by spontaneous or fast GI. Fifteen trials were recorded for each movement.

RESULTS AND CONCLUSIONS: The results showed that the two motor programs involved in STS-GI did not fuse into a single motor program. The interaction between the two motor tasks operated during the intermediate phase situated between the end of the APAs of the first motor task (STS) and execution of the second task (GI, Foot-off). During this phase the central nervous system adjust the postural parameters according to the "final" conditions of the first task and the speed of progression demand of the second task, i.e. according to the antero-posterior velocity of the centre of mass of STS and the intentional speed of gait either a braking or an acceleration occurred.

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Arm movements during split-belt walking reveal dominance of interlimb coupling

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INTRODUCTION: In gait, movements of the upper limbs (UL) show two types of coupling: 1) anti-phase coupling between ipsilateral UL and lower limbs (LL) to regulate vertical angular momentum of the body [1] and 2) anti-phase coupling between the ULs which individually appear to be in phase with the contralateral LL. The mechanisms underlying UL swing, i.e., due to passive mechanics or active control is still not understood. a split belt treadmill, in which different belt speeds create a need to adjust UL movements and bilateral symmetry, offers a means to investigate such UL and LL coupling. It is known that gait patterns between LLs on a split belt treadmill uncouple to ensure progression [2, 3]. The purpose of this study was to examine changes in UL movement as coupling between the LLs was altered.

METHODS: 11 healthy individuals walked on a split-belt treadmill with one of 4 speed ratios (2:2, 2:4, 2:6 and 2:8 km/h) with the speed of the left belt always at 2 km/h. Markers were attached according to a full body model and recorded by a 3-D Vicon motion analysis system. Calculations of UL and LL horizontal trajectory amplitudes were determined by subtracting the anterior range of motion of the elbow (UL's most consistent swing marker) and ankle markers. Temporal aspects of marker trajectories during each stride were quantified using Pearson correlations between contralateral upper/lower limbs (right UL/left LL, left UL/right LL) and UL/LL pairs (right/left UL, right/left LL). To examine phase delays between contralateral upper and lower limbs, the time of maximal anterior position of the ankle marker was subtracted from that of the elbow marker. A mixed model (accounting for missing data for one condition) was used to determine differences between belt speeds.

RESULTS: Increases in belt speed were accompanied with increases in right LL amplitude ($p < 0.001$) and decreases in left LL ($p < 0.001$) amplitude as shown previously [3]. This change in pattern between the LLs was not conserved within the ULs. As the right belt moves faster, increases were seen in amplitudes of both right ($p < 0.001$) and left ($p < 0.001$) ULs. Correlations between right UL/left LL ($p < 0.001$) and left UL/right LL ($p < 0.001$) trajectories increased as right belt speed became faster, suggesting that timing of contralateral upper/lower limb trajectories becomes increasingly matched regardless of side. As the right belt speed increases, the LL ($p < 0.001$) and UL ($p < 0.001$) became more out of phase (closer to a correlation of -1) which suggests a more precise gait pattern was used to regulate timing between the limbs. Delay analyses suggested that the ULs reached maximum horizontal displacement before the LLs and these peaks occurred closer in time as right belt speed increased ($p < 0.001$) in the left UL/right LL. For the right UL/left LL delay, the left LL became the leading limb in asymmetrical gait speeds (i.e., other than 2:2 km/h). This may be due to changes in limb amplitude and the UL will reach its peak later in time.

CONCLUSIONS: Since diagonal limbs show a higher correlation and a smaller delay at higher speed differences it is argued that the diagonal coordination is reinforced under these circumstances. In addition there is a clear dominance of the fast over the slow side since both arm movements follow the changes in fast leg amplitude only, presumably because of its larger effect on maintaining vertical momentum (see [1]). Finally, coupling between the ULs may be stronger than between the LLs since symmetry is maintained more rigorously in the UL.

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Motor patterns during walking on a slippery surface

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INTRODUCTION: Friction and gravity represent two basic physical constraints of terrestrial locomotion. It is also important to investigate the mechanisms and adaptation to slip exposure in the context of the prevention of potential falls and injury [1]. To get insights into the role of friction for bipedal gait, here we considered walking on a slippery surface as a special gait and investigated its various biomechanical and neurophysiological characteristics.

METHODS: Six subjects were asked to walk on the slippery surface (7-m-long, using oil, friction coefficient ~0.05) at a natural speed. We also recorded walking on the non-slippery floor at different speeds in order to match walking speed conditions. The kinematics of gait and EMG activity of 32 muscles were recorded bilaterally. Ground reaction forces were also recorded by means of a force plate located in the middle of the walkway. To analyse EMG patterns, we applied statistical analyses (factor analysis and non-negative matrix factorization) and we mapped the recorded EMG patterns onto the spinal cord in approximate rostrocaudal locations of the motoneuron (MN) pools [2].

RESULTS: The results revealed several idiosyncratic features of gait on the slippery surface. The step length and the cycle duration were significantly smaller compared to those on the normal floor at matched walking speeds. Ground reaction shear forces were very small during weight acceptance (first 20% of the stance phase), and foot motion resembled that of the non-plantigrade gait (without heel-to-toe rolling pattern). The planar covariance of the thigh-shank-foot elevation angles [3] in the sagittal plane (the shape of the gait loop) also reflected non-plantigrade gait. Prominent and systematic lateral trunk inclinations were observed on the slippery surface in all subjects and across all trials. The idiosyncratic feature of walking on the slippery surface consisted in a considerable decrement of lateral COM oscillations with trial repetition. About 90% of bilateral EMG activity could be accounted for by 4 basic temporal components linked to specific (foot touchdown) events. However, on the slippery surface the width of the main peak was wider. The mean level of MN activation of the lumbosacral enlargement was considerably (~2 times) higher on the slippery surface, mostly due to increased activity in the proximal leg muscles. The centre of MN activity in the lumbosacral enlargement showed two prominent oscillations within one gait cycle on the normal floor, and basically no oscillations on the slippery surface.

CONCLUSIONS: The results showed that successful walking on a slippery surface requires stabilization of the COM and hip in the frontal plane, which is learnt during subsequent trials. This stabilization is achieved by changing the characteristics of foot placement and lateral trunk tilts both during stance and swing. Motor patterns on the slippery surface are characterized by increased level of activation and by the absence of systematic displacements of the centre of MN activity in the lumbosacral enlargement. The latter finding may indicate a potential link between spatiotemporal organization of MN activity in the human spinal cord and plantigrade bipedal gait.

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Complex three-dimensional spine motions during target-directed movements of the trunk in sitting

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INTRODUCTION: Attempts to monitor 3-D spine motions, across multiple spine levels, have typically focussed on movements in the cardinal planes [1]. The purpose of the current study was to assess the inter-segmental motion of the spine in young, healthy subjects, during multi-directional target-directed movements of the trunk, in sitting.

METHODS: Subjects sat with their feet unsupported, and leaned toward suspended targets in 5 directions (Fig.1A), at 3 distances and heights, representing 15^{o} intervals based on the height of the subject's trunk (Fig.1B). A 6-camera, Vicon 512 motion analysis system recorded the inter-segmental spine kinematics, based on 7 marker triads (Fig.1C). Motions were named for the orientation of the rostral triad relative to the adjacent caudal triad (Fig.1C). A 3-way ANOVA, for each spine motion (flexion, side-bend, and axial rotation), was performed based on trunk level (6 levels: LLx to UTx), target distance (3 distances) and target direction (5 directions).

RESULTS: Significant main effects were found for each of the independent variables tested (trunk level, target distance, and target direction) for each spine motion (flexion, side-bend and axial rotation), along with several significant interaction effects. The inter-segmental angles at the point of peak trunk excursion, for target distance 3, are illustrated in Fig.2

CONCLUSIONS: These findings, and in particular the significant interaction effects revealed by the ANOVA, indicate that spine motion is complex, task dependent, and often unevenly distributed between spine levels. As such, multi-segmental analysis of spine motion should be adopted for all but the simplest of trunk movements. Such an approach may allow a more through investigation of the movement impairments that may exist in patients with mechanical low back pain [2], and various other neurological and neuromusculoskeletal disorders.

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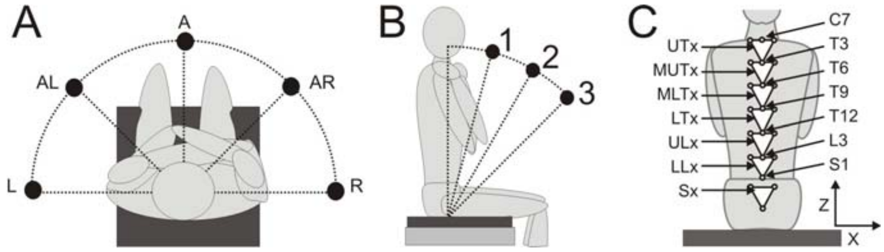

Fig.1 Experimental Setup

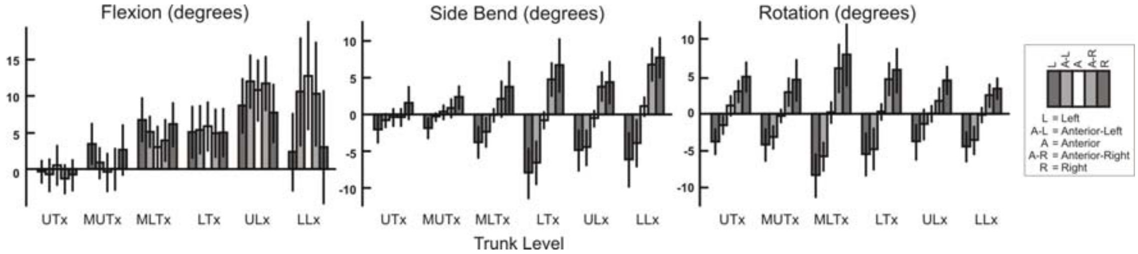

Fig. 2 Peak inter-segmental motions at target distance 3

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Action of communication: body anticipates voice

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INTRODUCTION: Postural correlates of vocal effort are rarely described in the literature while they are extensively used in the daily life during the life span. This study highlights the coordination between posture and voice during vocal effort, in order to determine whether body movement is a reactive side-effect or an anticipate integrant part of global communication. To answer this question, we propose a paradigm involving simultaneous vocal and kinematic recordings.

METHODS: Postural control was tested in 20 healthy adults performing vocal effort in standing position. They had simply to maintain efficient communication with a listener despite environmental increasing obstacles (distance and noise).

RESULTS: The main results that emerge from this study report that movement which accompanies vocal effort is structured and involves the whole body. The amplitude and duration of the movement increase along with increasing vocal effort. Movement clearly anticipates phonation. The head and the other parts of the body present specific patterns of movement. The head movement may be involved in the improvement of vocal efficiency and the forward trunk bending may emphasize the energetic/effortful aspect of the communication.

CONCLUSIONS: As it was initially speculated, axial movements anticipate voice and do not disturb postural control. Moreover, body orientation control is coordinated with vocal effort. Probably that postural anticipation may be to catch the auditor's attention and make him focus on the message's content.

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Effects of a fine motor task on postural balance while standing

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INTRODUCTION: During everyday life activities, postural balance is almost always combined with a secondary cognitive or fine motor task. Either task may increase postural demands and therefore the inverted pendulum stiffness, but fine motor tasks typically involve motion of which the inertia affects posture, so that most dual-task literature use cognitive rather than motor secondary tasks [1,2]. This study was aimed to investigate how a fine motor task with negligible motion affects postural balance compared to secondary cognitive tasks.

METHODS: Twenty five healthy adults (mean age = 34.5±9.1 years) were asked to perform a primary postural task of standing relaxed on 2 feet during 25 seconds (CONTROL). The secondary fine motor task existed of keeping a light anterior-posterior free-rolling cylinder on a tray in a central position, simulating balancing of a moving object (CYL). Cognitive tasks for comparison were the Brooks' spatial memory task (BROOKS) [3] and standing as still as possible (STILL). Centre of Pressure (CoP) was calculated from force platform recordings (Kistler, 1000 Hz, downsampled to 100Hz) and Centre of Mass (CoM) from kinematic recordings (Vicon, 100 Hz). Controlling and controlled variables were calculated as CoP-CoM and CoM, respectively [4]. Standard deviations and mean frequencies were compared using repeated measures ANOVA (significance level set at 0.05).

RESULTS: No differences were found for the controlled variable CoM between tasks. In anterior-posterior direction, mean frequency of CoP-CoM increased for cognitive tasks BROOKS and STILL, whereas CYL was not different from CONTROL (figure 1). In medio-lateral direction, mean frequency of CoP-CoM did not increase in any task relative to CONTROL, but BROOKS was lower compared to STILL and CYL.

CONCLUSIONS: In contrast to the cognitive tasks, the fine motor task did not result in higher inverted pendulum stiffness. Either the fine motor task was too easy, or existing theories concerning the effect of cognitive secondary tasks on postural balance do not hold for fine motor tasks. Characteristics of the fine motor task and a wider base of support compared to previous studies might explain the absence of effects in medio-lateral direction. Further research is being undertaken to identify the true nature of these findings.

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Fatigue-related temporal changes in inter-segmental coordination during repetitive reaching

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INTRODUCTION: Previously, we have described the changes in whole-body movement and muscle activity amplitude characteristics resulting from repetitive reaching during fatigue [1]. However, the effects of fatigue on inter-segmental coordination across the body, during a low-load repetitive reaching task, have not yet been well documented. The objective of this study was to assess the effect of fatigue on the temporal coordination characteristics of both postural and arm movement parameters during a repetitive reaching task.

METHODS: Healthy subjects (N=14) stood and performed a continuous reaching task (RRT) between two targets placed in front of the subjects' midline at shoulder height until reporting a perceived exertion of 8/10 or higher (Borg scale [2]) for the shoulder region of the dominant arm. Whole-body kinematics, forces under the feet and the electromyographic (EMG) characteristics of postural and upper limb muscles were recorded. Only data during the first and last minute which the RRT was performed has been analyzed to date representing No-Fatigue (NF) and Fatigue-Terminal (FT) data, respectively. EMG magnitude was quantified by the root-mean-square (RMS). The magnitude and occurrence of maximum velocity (expressed as a percentage of reach duration for the body's centre of mass (COM) and centre of pressure (COP), as well as the index finger tip (endpoint) were determined for each direction (medio-lateral (ML), antero-posterior (AP), superior-inferior (SI)), together with the sagittal plane flexion/extension angles of the shoulder and elbow joints. Inter-reach variability was calculated for every parameter using standard deviation measures. Maximum force output during maximal voluntary isometric efforts (MVIE) of the

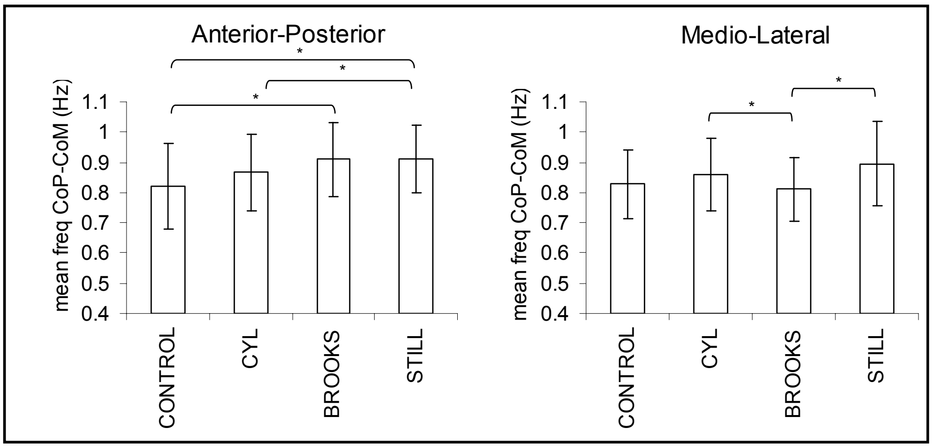

Fig.1 Mean frequency of controlling variable CoP-CoM (Mean ± SD) in anterior-posterior and medio-lateral directions

shoulder and elbow were measured pre- and post-RRT to confirm the onset of fatigue. Statistical analyses to compare outcome variable between the NF and NT conditions were performed using paired T-tests.

RESULTS: The time of endpoint maximum velocity in the AP direction occurs significantly later within the reach cycle during FT (NF: 46.8 ± 7.2% vs. FT: 50.7 ± 7.7%, p=0.025), while the timing of maximum COM velocity tended to occur earlier (NF: 61.0 ± 7.0% vs. FT: 58.1 ± 12.3%, p=0.064). Maximum velocities of the COM and COP increased in all directions with fatigue. Inter-reach variability in the following parameters increased with fatigue: Endpoint maximum velocity (ML), COP maximum velocity (ML), time to maximum velocity of endpoint (SI). Shoulder elevation MVIE decreased by 4.8% ± 8.2% (p=0.039) and trapezius EMG RMS increased by 46.5 ± 49.9 (p=0.002), confirming the presence of upper limb fatigue resulting from the RRT.

CONCLUSIONS: The closer timing of maximum endpoint and COM velocity in the AP direction during fatigue suggests an increase in temporal coupling between reaching and postural characteristics. This finding gives evidence to the adoption of a simpler and more en-block coordination strategy which may help to prolong successful task performance during fatigue. Increases in COM and COP maximum velocity and inter-reach variability with fatigue are consistent with the fatigue literature investigating similar tasks [3] and have often been associated with postural instability but could be linked to the search and adoption of the new COM-endpoint coordination strategies to take advantage of trunk movement to assist arm motion.

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Task-independent and task-specific trunk muscle synergies are recruited in bending and reaching

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INTRODUCTION: A growing body of evidence suggests that poor neuromuscular control of the lumbopelvic region is a significant finding in a large number of patients with mechanical low back pain (MLBP), and when unresolved, may play a key role in recurrence of symptoms. Despite findings of differences in trunk motor control between individuals with MLBP and healthy subjects, the altered neuromuscular strategies underlying these differences have not been satisfactorily characterized. Our goal was to first determine “typical” trunk muscle strategies by examining the grouping (or synergy) patterns of motor drives in healthy adults during several voluntary tasks. We tested the hypothesis that a small set of synergies and their motor drives comprised the basis for control of the trunk during bending and reaching tasks.

METHODS: Surface EMG activity representing 10 trunk muscles was recorded from 10 healthy adults during 3 sagittal plane tasks: 1) forward bending and return to standing (FWB), 2) bilateral forward reaching (Rch), and 3) bilateral forward reaching holding a load (RchLD). EMG signals were rectified, smoothed and normalized to unit variance prior to decomposition of the multidimensional data set. Several methods have been developed to examine coordination and dimensionality reduction in EMG patterns. These include applications based on variance (principal components analysis, factor analyses). We utilized independent component analysis (ICA) which is based on mutual information independent of the magnitude of variance [1]. ICA returns a weight matrix representing synergies and the activations that capture the phasing and temporal patterning of the drives. We used the ICA weight matrices to identify the lowest numbers of synergies needed to capture 80-90% of the normalized variance of the original patterns. We also tested how well correlated the most prevalent (highest variance) synergies were across individuals and the different tasks.

RESULTS: Five muscle synergies were required to capture 80% of the variance of the original signal and this was consistent across tasks (FWB-84(7)%; Rch 83(4)%; RchLD- 85(3)%). There was strong mean correlation of the first 5 drives across subjects within each task (FWB .93(range .88-.98); Rch .84(.72 - .93); RchLD .77(.56 – 94)). The lower correlation in the loaded reach task is attributed to several subjects (4/10) presenting with a muscle synergy projecting a flexor/extensor co-activation. This specific motor behaviour accounted for considerable reconstruction in these subjects. Similar synergies were used across the 3 tasks, but were recruited differently (with differing strengths). The FWB and Rch task shared 4 of the 5 most common synergies, while Rch/RchLD and FWB/RchLD shared 3. Both FWB and RchLD had 1 unique or task-specific drive synergy. In FWB this unique drive was present in 6/10 subjects and projected to the lumbar multifidus muscles. In the loaded reach the task-specific synergy projected to all the recorded trunk extensors, contributed highly to the reconstruction and was used by 9/10 subjects.

CONCLUSIONS: Our results suggest that a small set of synergies comprise the basis for trunk control during sagittal plane tasks. The robustness of the synergy organization across individuals and tasks suggests that task-independent trunk muscle synergies simplify the underlying muscle coordination for single plane motions. However, unique synergies were present in the task that required control of a larger off-axis load. We believe this analysis offers promise for characterizing trunk neuromuscular control and that additional subjects, trunk muscles and tasks will provide an improved understanding of trunk control in healthy and patient populations.

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Maintenance of postural equilibrium following antero-posterior translations in sitting

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INTRODUCTION: Postural stabilization strategies can be investigated by inducing sudden displacements of the support surface. Although postural reactions in healthy individuals in the seated position have previously been described and perturbation direction has been shown to influence the response of the trunk [1], the effect of perturbation direction on the response of the neck has not been studied. The first objective of this study was to characterize kinematic and electromyographic postural stabilization patterns of seated healthy individuals. The second objective was to compare stabilization patterns to forward and backward translations.

METHODS: Ten individuals with no history of back or neck musculoskeletal disorders participated in this study. Participants sat on a chair bolted to a moveable support surface. They were exposed to a randomized sequence of 15 perturbation trials (displacement = 15 cm, max acceleration = 1.2 m/s^2), with 5 forward translations, 5 backward translations and 5 unperturbed trials. Motion of the head, arm and trunk segments was analyzed using markers placed on anatomical body landmarks. The activity of 16 muscles of the neck and trunk was acquired using bipolar surface electrodes. Kinematic data was used to compute head, trunk, and neck angular displacements as well as abdomen, lower thorax, upper thorax, and head centers of mass (COMs). Moments of force at the C7-T1 and L5-S1 levels were computed using a top-down, inverse dynamics approach.

RESULTS: For forward translations, trunk and head segments first responded by extension, and then reversed into flexion 679±67 ms and 817±110 ms, respectively, after the onset of platform movement. Although the neck first moved into flexion in most participants, motion reversed to extension and most of the displacement occurred in extension. Moments of force at the trunk and neck were initially flexion moments followed by extension moments. Neck and trunk flexor muscles were activated first, followed by the extensor muscles. The opposite pattern was observed following backward translations with trunk and head segments first responding by flexion and reversing into extension 737±65 ms and 861±111 ms, respectively, after the onset of platform movement. The initial moments of force were extension moments and extensors were activated first. Both forward and backward translations thus provoked mainly eccentric contractions. In response to perturbations, the trunk segment reached its first peak angular position (711±70 ms) earlier than the neck (1099±146 ms). However, there was no significant effect of perturbation direction on the amplitude and the time-to-peak of the first angular peak. Although there was no effect of perturbation direction on COM onsets, forward translations provoked greater COM displacements (17.7 vs 16.3 cm). When flexor onsets following forward translations were compared to extensor onsets following backward perturbations, no significant differences were found.

CONCLUSIONS: Forward and backward translations provoke postural reactions which display an opposite flexion/extension pattern but which are qualitatively similar. However, forward translations of the same magnitude or acceleration provoke greater COM displacements. This response can be explained by the higher postural threat in a forward translation (the trunk is closer to the posterior border of the base of support than it is to the anterior border) and/or by a greater compliance of the trunk in flexion. The fact that COM displacement is greater following forward translations suggests that the trunk follows the platform motion more closely instead of leaning backward.

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The interaction of posture and locomotion for stability

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INTRODUCTION: Upright bipedal locomotion has evolved to free the hands for tool use and consequently, concentrates the majority of its weight higher up in the trunk. This makes the human body inherently unstable, requiring a complex control system to maintain balance during locomotion. A portion of that stability is derived from the dynamics of the gait cycle, leading to an emphasis on measures such as stride variability and frequency. However, another source of stability is achieved through processes operating at frequencies other than the gait cycle. Here we show how vision stabilizes balance at frequencies other than the gait frequency. These processes reveal how the interaction between posture and locomotion achieves flexible balance control during locomotion.

METHODS: Sixteen subjects walked or stood on a treadmill in three speed conditions (posture, 1 km/hr, 5 km/hr) in front of a visual scene consisting of 500 randomly oriented triangles in a 2.5 m by 1.8 m virtual display. The triangles translated in the A/P direction in a low and high amplitude condition (filtered white noise) for 2 minutes. Frequency response functions (FRFs) were computed as the A/P displacement of 21 bilateral kinematic markers in response to the visual scene translations. Gain and phase were computed from across-subject FRFs binned from 50 frequencies up to 2.5 Hz.

RESULTS: At low frequencies of body movement, all body segments were in-phase in the posture and locomotion conditions. At higher frequencies around 1 Hz, trunk/leg coordination shifted to an anti-phase relationship in both the posture and locomotion conditions, suggesting similar postural dynamics. Gain of body segments relative to the visual display during locomotion was much higher than in the posture condition suggesting stronger coupling to the visual stimulus. Gain during both the posture and locomotion conditions decreased as the amplitude of the visual signal increased, indicating downweighting of the visual stimulus. However, higher gain ratios of low amplitude/high amplitude conditions during posture than locomotion reveal that downweighting was more pronounced in the posture condition.

CONCLUSIONS: These results suggest that: 1) similar postural coordination patterns are evident during both quiet stance and locomotion; 2) coupling to a visual stimulus is potentially much stronger than during quiet stance; and 3) intra-modal re-weighting is weaker during locomotion. Potentially stronger coupling with less downweighting during locomotion may explain why all subjects perceived the moving visual stimulus to be stationary (“frozen”) during locomotion conditions while image movement was perceived in the posture condition. The complexity of locomotion may warrant more reliance on sensory information for stability than the simpler task of maintaining quiet upright stance.

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Anticipatory control of medio-lateral stability during coordination of rapid forward stepping initiation with controlateral and ipsilateral arm raising

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INTRODUCTION: Stepping initiation (SI) has classically been defined as the transient period between steady postural state and the time of swing foot contact (FC) with the support surface [1]. It is composed of a “postural phase” that precede the stepping heel-off (HO) time (the so-called “anticipatory postural adjustments”, APAs) followed by the “execution phase”. Along the medio-lateral (ML) direction, APAs include a centre of pressure (CoP) displacement towards the swing leg side which acts to shift the centre of gravity (CoG) in the opposite direction, and thereby provide an initial CoG velocity at the start of the step [2]. This anticipatory CoG motion is presumed to be directed to minimize the natural tendency of the CoG to fall “ballistically” toward the swing leg side during the SI execution phase [3]. The current study questioned how, in young healthy adults, the central nervous system (CNS) controls the ML stability during the coordination of forward stepping initiation (SI) with ML arm raising. It was hypothesised that the CNS is able to scale the ML APAs amplitude for stepping in function of the biomechanical consequences of the forthcoming upper limb movement on the ML stability.

METHODS: Subjects (N=7) purposely performed series of SI with the contro- or ipsilateral leg, in isolation or in combination with ML raising with the dominant arm. It was assumed that raising the arm while stepping with the *ipsilateral* leg will enhance the natural tendency of the CoG to fall towards the swing leg. In contrast, raising the arm while stepping with the *controlateral* leg will attenuate this tendency. To vary the influence of the arm movement on the ML stability during stepping, the raising was performed with or without an additive 1.5 kg inertia attached to the wrist. The movements were performed at a maximal velocity and in a self-paced mode on a large force-plate. In addition, one mono-axial accelerometer was affixed at the dominant wrist, and pressures captors were glued under the toes and heels of both limbs.

RESULTS: In all conditions, large and consistent ML APAs were detected. Statistical analysis (repeated-measures ANOVA) showed that when the arm raising was coordinated with the ipsilateral SI, the amplitude of the ML APAs for stepping (in term of maximal anticipatory CoP displacement towards the swing leg side and ML CoG velocity/displacement towards the stance leg side) was increased as compared to an isolated stepping. The adjunction of the inertia to the wrist further enhanced this effect. Though, the ML stability at the time of swing FC - which was estimated with the ML CoG velocity/displacement towards the swing leg side and with the step width at FC - was degraded when the arm raising was superimposed on the SI. In contrast, when the arm raising was coordinated with the controlateral SI, the amplitude of the ML APAs remained unchanged as compared to an isolated stepping while the ML stability at FC was improved.

CONCLUSIONS: These whole results are in line with the proposed hypothesis that, in young healthy adults, the CNS scales the amplitude of the ML APAs in function of the biomechanical consequences of the forthcoming arm raising on the ML stability. These basic results may contribute to the understanding of sideway falls etiology in persons living with postural impairments such as the elderly and neurological patients with balance disorders, as many daily tasks involve the coordination of upper and lower limbs.

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The invariance of center of pressure release in sit-to-stand

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INTRODUCTION: A successful sit-to-stand (STS) involves the transfer of horizontal to vertical momentum to create seat-off. A braking force under the feet initiates this transfer. We believe that the onset of this braking force is controlled by the center of pressure release (COPR), the correct timing of which is important to prevent 'sit-back' failures. In addition, it is our hypothesis that COPR should remain invariant to seat-off even though the timing and amplitude of other parameters of STS may change.

METHODS: Nine healthy female subjects (24.9±2.5 years) volunteered to participate in this study. The subjects performed STS trials at a self-selected normal speed and a faster than normal speed. Three-dimensional motion analysis was performed, and kinematic and kinetic data were collected for 5 successful trials for each condition. Data were analyzed using Visual 3D and a paired t-test ($p<0.05$) determined significance. Dependent variables included timing of events relative to movement onset and seat off, hip flexion velocity and the slope of the center of pressure (COP) and the braking force.

RESULTS: Relative to movement onset there were significant differences between normal and fast speeds of STS for time to seat-off, onset of braking force, COPR and peak braking force. These events occurred earlier for fast STS. Hip flexion velocity and peak braking force were greater for the fast STS. Even though the above parameters differed with the speed of STS there were no significant differences for the time from both COPR and peak braking force to seat-off.

CONCLUSIONS: The above data indicate that seat-off and other timing variables occur earlier with an increase in the speed of STS. With an increase in speed there is an increase in the peak posterior ground reaction force or braking force. We do know that tibialis anterior is activated early in STS [1]. In a closed chain position this activity will generate a posterior movement of the COP and an anterior or propulsive ground reaction force. The interaction of tibialis anterior, soleus and COP is well established in the gait initiation literature [2]. Given the timing differences between speed of STS then the rate of backward movement of the COP has to be modulated to allow the invariant timing of COPR with respect to seat off. The slope of COP was significantly greater for fast STS.

This presentation provides our initial data on the control of the COP and the invariance of COPR during STS. Of further interest is the affect of other STS variables on COPR as well as the control of COPR in those with abnormal ankle muscle control, such as patients with Parkinson's disease [3].

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Local and global effects of arm perturbation during walking

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INTRODUCTION: During anti-phase arm swinging in quiet standing, when one arm is transiently arrested (arm perturbation), the non-perturbed arm waits at either the extreme forward or backward position until the perturbed arm resumes motion and reaches the opposite extreme position [1]. This type of rhythmical arm movement is likely generated by a common mechanism linking movements of both arms. Indeed, a common coordinative mechanism may link both arm and leg movement together during human locomotion resulting in coordination of all four limbs [2]. This linkage includes anti-phase arm movement with each movement of each arm linked to that of the paired contra-lateral leg. We hypothesized that during walking all four limbs are controlled as a single unit such that a perturbation of one limb will affect the coordination between all four limbs.

METHODS: Seven healthy subjects walked on a self-paced treadmill at 1 and 1.2 times their comfortable speed (metronome-paced) for 24, 40 s trials. In each trial, one arm was mechanically perturbed (~250 ms) during the forward swing phase. Perturbations occurred in three to four randomly selected cycles during each trial. Subjects were instructed to continue walking even if the perturbation briefly interrupted their gait. Arm, leg, head, and trunk movements were recorded using a three-dimensional motion analysis system (sampling rate at 120 Hz; Vicon-512, Oxford, UK). Electromyographic signals were recorded from eight arm and leg muscles using a telemetric system (Noraxon, Scottsdale, USA).

RESULTS: After perturbation, walking rhythm continued as before, but arm rhythm was disrupted. Rhythmical arm swinging resumed after one to three cycles with a phase delay. Perturbation of the arm resulted in kinematic and reflex responses in muscles of the ipsilateral and contralateral shoulder and elbow in the majority of cases (approximately 65-75%). A kinematic response to arm perturbation occurred less often in the ipsilateral (18-26%) and contralateral (15-27%) leg.

CONCLUSIONS: The rapid resumption of coordination between the arms and legs suggests that the resetting and adaptation of the pattern for all four limbs during locomotion is centrally mediated.

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Synchronised reactive motor control for the co-ordination of arm and body posture stability when unexpected balance perturbation

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INTRODUCTION: This study concerns the adaptive control of goal-directed action in 3D space when multi-joint co-ordination of the whole body is required (hand reaching with balance control). It raises the question of the synergistic adjustment of multiple motor commands send to collaborative motor sub-systems that are at once concurrent and competitor due to the use of common perceptual and motor resources. Despite the important knowledge concerning the adaptive control of multi-segmental movement, it is not clearly understood how the central neuromotor system control in parallel separate neuromotor systems involved in a same motor task. This study addresses more particularly the question of the interactive control of the hand and the standing posture involved in an accurate hand-positioning task. The aim is to clarify the on-line compensatory motor processes used to keep the stability of the hand on a visual target when an unpredictable whole-body balance perturbation is suddenly applied and trigs important arm and postural motor correction to keep the hand stabilised on its spatial goal.

METHODS: Subjects, in a standing posture, had to maintain the right hand stabilised on a visual target. Two level of hand positioning accuracy was imposed (low or high). When the hand was stabilised, in 25% of the trials an unpredictable balance perturbation was applied (a secured 1kg or 5kg load-impact located at upper spine level). Subject was instructed to maintain the hand on the target as accurate as possible and to keep a stabilised upright standing despite the postural perturbation. Arm and body kinematics, force plate and electromyography data was recorded to quantify the postural stabilisation and hand accuracy when reactive motor responses.

RESULTS: Results show that at kinematic and motor command level, the load perturbation was instantaneously integrates at both postural and arm control level. Despite its unpredictable status and the unanticipatory reactive processing, the perturbation triggered fast compensatory motor responses that maintained the hand on target in a controlled balance. Results indicate than an interactive and synergistic control based on the visual target referencing was tuned between arm and postural correction for a shared stabilisation of the balance and the hand. That shows that a mutual servoing of separate perceptual-motor command allows the synchronisation of multi-joint activities to maintain an imposed level of spatial accuracy.

CONCLUSIONS: The mechanical effect of the load perturbation seems to have been integrated in each of the two specific visuo-motor reference frames (visuo-manual and visuo-postural). This allows to adjust synergistically each motor sub-system to the other for a global compensatory motor strategy. It also indicates that the status of the primary vs. secondary compensatory motor commands depend mainly on the new motor functionality that emerges from the re-updating of the visuo-motor frame of reference when rapid adaptation are imposed by the environment.

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Improved coordination of reach-to-grasp post-stroke: learning the movement vs. changing the strategy

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INTRODUCTION: While impairments of upper-extremity function are among the most persistent and disabling following stroke, identification of effective therapeutic interventions has remained elusive. Our previous work demonstrated that a hybrid intervention of combined functional task practice (FTP) and dynamic, high-intensity resistance training (STR) produces significant improvements in upper-extremity function, which exceed those resulting from FTP alone. Importantly, these functional improvements occur without exacerbation of either the hyperreflexic or hypertonic components of spasticity. Here, we report results from our current longitudinal study where we investigate differential effects of FTP and STR on both clinical function and motor control strategies during a functional, goal-directed upper-extremity task.

METHODS: Eight hemiparetic subjects (mean 14.8 (±2.7) months post-stroke, 7 males) were randomized to either a Control (FTP) or Experimental (STR) treatment. Four healthy subjects served as reference controls. A battery of evaluations conducted at baseline and following 10 weeks (30 sessions) of treatment included clinical assessments and kinematics. Subjects performed self-paced reach-to-grasp using the paretic upper-extremity while seated in a straight-back chair with the trunk stabilized.

RESULTS: All stroke subjects demonstrated clinical improvements (not reported here). Both groups improved coordination of reach-to-grasp as revealed by a shift towards normal in: time to maximum hand velocity, inter-joint coordination and fewer sub-movements. However, differential effects were revealed in active ROM: the control group decreased excursion in shoulder flexion, elbow extension and supination, while the experimental group increased excursion in elbow extension and supination.

CONCLUSIONS: Improved control of reach-to-grasp following FTP involves reduced joint displacements, movement speed and index of curvature, which together suggest learning of the existing movement strategy. In contrast, notable changes following STR involve improvements in isolated elbow motion and inter-joint coordination, which together suggest modification of the movement strategy.

	Healthy mean (SE)	Control group (FTP)		Experimental group (STR)	
		Pre	Post	Pre	Post
Movement Time (s)	0.9 (0.1)	5.1 (0.9)	3.1 (0.4)	2.4 (0.5)	2.3 (0.3)
Max velocity (cm/s)	89.9 (10.1)	83.2 (13.3)	62.8 (13.8)	75.9 (4.2)	71.1 (4.6)
Time to peak hand velocity (%)	25.9 (4.7)	16.9 (3.5)	29.3 (7.0)	14.6 (4.1)	32.0 (2.7)
Sub-movements	0 (0.0)	7.5 (1.6)	4.3 (1.1)	4.6 (1.2)	1.8 (0.9)
Index of curvature	1.7 (0.0)	3.5 (0.4)	1.9 (0.1)	2.2 (0.2)	2.0 (0.2)
Discrete relative phase (°)	116.9 (28.4)	-74.1 (54)	2.1 (15)	33.4 (37)	50.7 (19.1)
ROM, Shoulder Flexion (°)	25.8 (1.4)	25.8 (5.0)	23.5 (2.4)	29.0 (3.1)	30.2 (1.6)
ROM, Elbow extension (°)	45.5 (10.2)	21.8 (4.0)	17.1 (2.2)	36.7 (10.5)	66.1 (40.2)
ROM, Elbow supination (°)	25.5 (3.1)	19.0 (3.13)	17.0 (3.1)	15.5 (1.3)	22.5 (3.1)
Trunk displacement (cm)	0.4 (0.0)	9.4 (1.0)	4.12 (0.7)	3.83 (1.2)	4.0 (0.7)

Table 1. Mean values (SE) of kinematic variables

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Differential adaptations in reaching control post-stroke: movement execution vs. coordination

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INTRODUCTION: Although weakness is among the most disabling problems post-stroke, traditional clinical doctrines proscribe strengthening. Our previous work, demonstrated that a hybrid intervention of combined functional task practice (FTP) and dynamic, high-intensity resistance training (STR) produces significant improvements in upper-extremity function which exceed those resulting from FTP alone. Here, we report results from a longitudinal, cross-over design where we investigate both differential and treatment order effects of FTP and STR on clinical function and motor control strategies for unconstrained reaching.

METHODS: Four low functioning hemiparetic subjects (mean 20.9 (±2.7) months post-stroke, 3 males, Fugl-Meyer UE motor score: 24-39/66) were randomized to either a Control (FTP>STR) or Experimental (STR>FTP) treatment order. Each treatment block involved 10 weeks (30 sessions). Evaluations were conducted at: baseline, post-Treatment-1, post-Treatment-2 and at 6 month follow up. Fast, open-ended forward reaching (target 153 cm high, placed at 110% of arm length) was performed while subjects were seated in a straight-back chair with the trunk stabilized.

RESULTS: While improvements in clinical assessments (not reported here) were similar following FTP and STR, reaching kinematics revealed differential treatment effects. Movement speed and active ROM improved more notably following FTP. Index of curvature, accuracy and inter-joint coordination improved more notably following STR (Table 1). As in our previous work, STR did not exacerbate spasticity (Changes in Mod. Ashworth scale: STR (0 to -1.5 points), FTP (0 to -2 points)).

CONCLUSIONS: Differential effects revealed here suggest that each intervention approach produces unique adaptations in upper-extremity reaching: FTP affects movement execution, while neural adaptations in response to STR influence movement coordination. The experimental treatment order appears to produce both greater improvements and retention on all parameters except index of curvature.

	Healthy	FTP >STR				STR > FTP			
		Base	FTP	STR	6 mo	Base	STR	FTP	6 mo
Max Velocity (cm/s)	317.30 (±22.75)	108.8	117.4 (7.94%)	113.88 (-3.04%)	126.34 (10.94%)	154.50	152.65 (-1.20%)	212.50 (39.21%)	221 (4.00%)
Accuracy (cm) (Endpoint Error)	39.35 (±2.27)	67.75	66.87 (1.31%)	65.77 (1.65%)	62.21 (-5.41%)	52.85	44.55 (15.70%)	44.90 (-0.79%)	45.70 (1.78%)
Index of Curvature	1.08 (±0.01)	2.79	1.86 (33.33%)	1.20 (35.48%)	1.56 (-30%)	1.26	1.16 (7.94%)	1.22 (-5.17%)	1.23 (-0.41%)
Inter-joint coordination (°)	-18.89 (±10.61)	10.16	17.45 NA	-35.41 NA	36.81 NA	6.35	-18.01 NA	7.97 NA	-42.69 NA
ROM Shoulder Flexion (°)	99.23 (±12.17)	42.13	50.01 (18.72%)	50.45 (0.87%)	49.46 (-1.96%)	59.50	60.10 (1.01%)	83.80 (39.43%)	69.30 (-17.30%)
ROM Elbow Flexion (°)	62.43 (±1.70)	32.00	34.74 (8.56%)	31.35 (-9.75%)	35.94 (14.62%)	40.85	43.95 (7.59%)	49.90 (13.54%)	45.05 (-9.72%)

Table 1 Mean values (SE) for 4 healthy controls; mean and mean percent change in 4 hemiparetic subjects (positive % change indicates improvement)

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Dual task effects during swing and stance phases of gait after stroke: a pilot study

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INTRODUCTION: Gait speed is an important determinant for functional walking; however, other temporal parameters of gait, such as the amount of time spent in double limb support (DLS) can reveal more about gait stability. Dual task effects associated with the distinct phases of the gait cycle during continuous overground walking in people after stroke have not been explored. The purpose of this pilot study was to investigate the effects of concurrent cognitive tasks on DLS and swing duration.

METHODS: Thirteen community-dwelling individuals post stroke participated in this study. The gait analyses reported here required footfall data from both the paretic and nonparetic limbs, thus the results are based on a subset (n=8) of the sample for who data were available for both feet. The 8 participants (6 males) were 57.5 ± 18.3 yrs, with post-stroke onset 7.6 ± 4.2 months and gait speed 0.87 ± 0.35 m/s. The participants performed 3 cognitive tasks (auditory 1-back, visuospatial clock task, spontaneous speech) in random order, in sitting and in combination with walking. The continuous walking task was also performed without any additional cognitive task before and after the 3 dual tasks. Gait data were acquired using footswitches while the participants walked continuously around an oval track (27.5m). Footfall data were synchronized with the stimulus and response data for the cognitive tasks. Each task lasted approximately 3 minutes, resulting in acquisition of 125 ± 46 continuous strides for analysis. DLS and swing duration were expressed as percentage of gait cycle duration.

RESULTS: DLS increased under dual task conditions, but this difference was not statistically significant ($p=0.11$). Interestingly, the trend for an increase in DLS carried over to the last single-walking trial despite a relative increase in speed. There was a significant dual task effect for swing duration of the nonparetic limb: it was significantly reduced in the 3 dual task conditions compared to walking alone ($p<0.05$). This effect was not observed for paretic limb swing duration.

CONCLUSIONS: Under dual task conditions, participants tended to increase the proportion of each gait cycle spent in DLS and significantly reduced the duration of single limb support on the paretic leg (faster nonparetic swing). Despite a return to usual gait speed when participants were asked to walk without any additional cognitive task after the dual tasks were completed, this temporal pattern remained. This is likely a practice effect due to the length of the continuous walking trials; participants walked 9-12 minutes in total under dual task conditions. The findings from this pilot study suggest that further research evaluating cognitive-motor interference effects on different phases of the gait cycle is warranted to identify and characterize dual task effects on markers of gait stability after stroke. Knowing how swing and stance are affected by dual task gait may help clinicians target assessment and treatment to improve functional walking.

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Analysis of Postural oscillation in Children with Cerebral Palsy

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INTRODUCTION: It is believed that static balance undergoes changes in children with cerebral palsy (CP). Thus, we analyzed static balance in 19 children with the aim of comparing balance between healthy children and those with CP[1-3].

METHODS: The sample was divided into two groups – one with 10 children diagnosed with diparetic CP (CPG) and a control group (CG) with nine healthy children, all capable of remaining in an orthostatic position without support and obeying spoken commands. The assessment of postural oscillation was performed with the children barefoot, arms alongside the body and looking toward a fixed point while standing on an unrestricted base for the feet. Data collection was performed using a TEKScan force platform with 30-second duration for each condition.

RESULTS: The children had an average age of 7.9 years (±2.07) in the CPG and 7.5 years (±1.58) for the CG. Postural oscillation data in the anterior-posterior and medial-lateral directions were analyzed using the Data Analysis and Technical Graphics Origin 6.0 program. Statistical analysis of the mean oscillation value in the conditions of eyes open and eyes closed did not differ significantly between groups. However, there was a significant difference in mean anterior-posterior oscillation between groups (p=0.00) (Figure 1). The groups behaved similarly with regard to the visual deprivation.

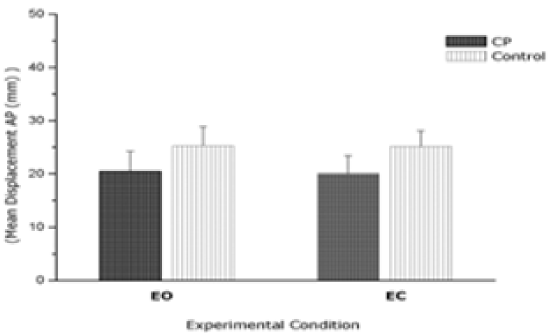

Fig.1 Intra-group comparison of mean oscillation values in the condition of eyes open and eyes closed.

CONCLUSIONS: We conclude that children with CP exhibit less postural oscillation in comparison to healthy children under the same conditions.

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Inappropriate calf muscle activity during external perturbation as a measure of severity of HSP

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INTRODUCTION: Hereditary spastic paraparesis (HSP) is a progressive neurodegenerative disease characterized by corticospinal axonal degeneration and severe lower limb spasticity. The lower limb spasticity, particularly of the calf muscles, puts HSP patients at risk of falling when they are exposed to external balance perturbations that stretch these muscles. Indeed, previous research has shown evidence of inappropriate calf muscle activity in HSP patients after external perturbations, particularly in the 'toes-up' direction [1]. The aim of this study was to investigate to which extent the inappropriate calf muscle responses to unexpected external perturbations are associated with the degree of corticospinal tract degeneration as assessed by transcranial magnetic stimulation (TMS) of the anterior tibial muscle (TA). Of the leg muscles, the TA acts under most corticospinal control (i.e. more than the calf muscles) [2] and is therefore used to measure the degree of corticospinal tract degeneration in this study.

METHODS: Five HSP patients (aged 39-62 years) participated in this study. They were exposed to balance perturbations by sudden support surface rotations of 6 degrees. The protocol consisted of 24 perturbations in unexpected directions (at random in left, right, toes-up, and toes-down directions), of which we only used the 'toes up' perturbations in this study. Electromyographic (EMG) data were recorded from the left medial head of the gastrocnemius muscle (GM). The main outcome was the maximal calf muscle activity during the first 220 ms after the perturbation. In addition, corticospinal integrity was measured using motor evoked potentials (MEP) and compound muscle action potentials (CMAP) from the left TA. The stimulus intensity for the MEPs was set at 100% of the stimulator output capacity (1.4T) and the stimuli to the motor cortex were delivered over the vertex using a double-cone coil. The cortex was stimulated while the TA was relaxed (MEP_{rel}) and pre-activated (MEP_{fac}). Peak to peak amplitude of the MEPs was expressed as a percentage of the amplitude of the CMAP.

RESULTS: All patients showed increased amplitudes of the calf muscle responses to external balance perturbations (0.13 to 0.47 mV) compared to controls (~0.09 mV). Additionally, the corticospinal tract is affected in these patients as we found reduced MEP amplitudes in both relaxed target muscles (median 2%, range 0 to 8%, compared to normal values in literature around 20%[3]) and facilitated target muscles (median 18%, range 9 to 65%, vs normal values in literature around ~60%[4]). The three patient with (almost) absent MEP_{rel} (≤2%) and the lowest MEP_{fac} (≤18%) showed the most inappropriate calf muscle responses to balance perturbations (>0.23mV), whereas the two patients with the highest MEP_{rel} (>6%) and MEP_{fac} (>30%) had the least inappropriate calf muscle responses (≤0.15mV).

CONCLUSIONS: The results of this study show that, with increasing severity of the disease, patients become more vulnerable to balance perturbations that stretch the calf muscles. These results may explain why patients experience difficulties in maintaining balance and report frequent falls in daily life.

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Simultaneous measures of kinematics and fMRI: compatibility assessment and case report on recovery evaluation of one Stroke patient

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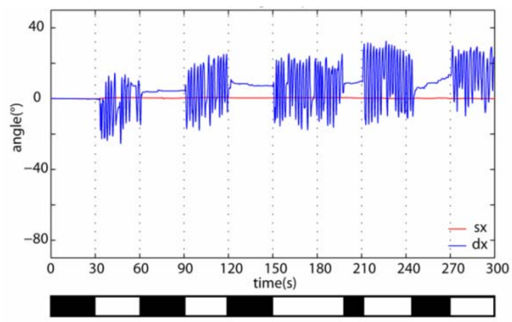
INTRODUCTION: In functional Magnetic Resonance Imaging (fMRI) studies of complex motor tasks, movement amplitude, velocity and frequency should be controlled because inconsistency in those parameters may alter the extent, the intensity and the patterns of motor cortical activations [1]. In this study the kinematics of a defined motor task was measured along with fMRI using a motion capture system.

METHODS: The compatibility between the MRI system and the optical motion capture system was evaluated. Then, a fMRI block-design protocol combined with motion capture was defined. A preliminary assessment of clinical applicability was carried out by pre- and post rehabilitation acquisitions on a hemiparetic patient performing ankles dorsal- plantar-flexion.

a)



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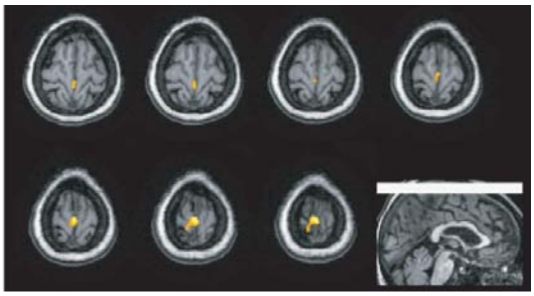

c)

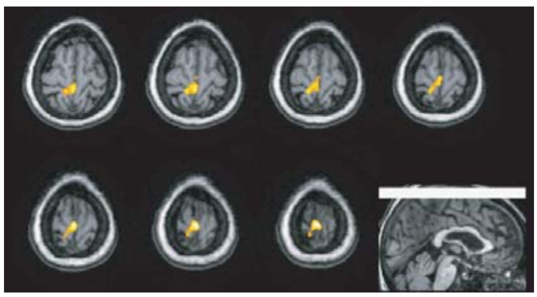

Fig 1: Results obtained by the patient healthy foot at hospitalization. Panel (a) reports the ankle angle and the bar which represents the re-defined design matrix. The activation found using the standard and the re-defined design matrix for statistical analyses are shown in panels (b) and (c) respectively.

RESULTS: The integrated set-up proved to be reliable: the loss in signal to noise ratio on the images was negligible and the kinematics data was not compromised. The definition of task regressors for fMRI analysis not according to the required but to the measured movement led to more consistent activation maps. These findings were especially evident in the hemiparetic patient pre-rehabilitation (Fig. 1). After one month of rehabilitation, a good fulfillment of temporal sequence was achieved. In addition, the greater extension of activations found can be justified with the greater movement amplitude and the higher execution frequency. Finally, the correlation between the angle of the moving and still ankle allowed the detection of possible mirror movements; such information leads to a correct interpretation of indexes on the inter-hemispheric balance of the activation maps.

CONCLUSIONS: The quantitative measure of movement enriches the information rising from fMRI and becomes crucial for the evaluation of motor recovery in neurological patients where large differences between planned and performed motion can be expected.

ACKNOWLEDGEMENTS: This work was supported by the Italian Space Agency and by the Italian Institute of Technology.

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Vibration elicits involuntary, air-stepping in individuals with spinal cord injury

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INTRODUCTION: There are more than 250,000 individuals in the United States living with spinal cord injury (SCI). One consequence of SCI is the disruption of communication between the brain and the spinal cord resulting in impaired activation of the locomotor central pattern generator (CPG). There is evidence that these CPGs remain active after SCI [1]. Evidence suggests that vibration elicits movements that may be driven by the locomotor CPG. The primary aim of this study was to determine if vibration elicits air-stepping responses in individuals with SCI as it does in non-disabled (ND) individuals [2].

METHODS: Subjects were 19 individuals (13 motor-incomplete [MISCI] and 6 motor-complete [MCSCI]) with chronic (≥ 1 year) SCI at or above T10 and 8 ND individuals. Subjects were positioned in side-lying, and vibration was applied to the quadriceps, hamstrings, or tensor fascia latae (TFL) to elicit involuntary air-stepping. Kinematic data acquired from 3D motion capture was used to quantify hip and knee angles during vibration-elicited air-stepping. Consistency was defined as the repeatability of the hip-knee coupling relationship over multiple cycles, which represents the strength of the intralimb coordination. Robustness was defined as the area of the space circumscribed by the step cycle, which represented the size of the hip-knee movement.

RESULTS: Vibration did elicit air-stepping in subjects with chronic SCI, with vibration of the TFL producing the most consistent and robust responses. Severity of spinal cord injury did not influence the consistency or robustness of the vibration-elicited air-stepping response, as air-stepping was elicited in both those with MISCI and those with MCSCI (see Fig. 1). However, the air-stepping responses elicited in subjects with SCI were not as consistent or robust as those elicited in ND subjects. In subjects with SCI, participation in locomotor training did not significantly influence robustness or consistency of the responses. However, there was a significant increase in consistency and robustness of the air-stepping responses with repeated testing.

CONCLUSIONS: These findings confirm that vibration elicits involuntary, air-stepping in individuals with SCI, just as it does in ND individuals. Vibration to the TFL appears to provide a potent source of excitation to the locomotor CPG. In individuals with SCI, vibratory input appears to induce plastic changes in the spinal circuitry that persist for up to 12 weeks.

ACKNOWLEDGEMENTS: This work was supported by the National Institutes of Health [R01HD41487; EFF] and the Miami Project to Cure Paralysis.

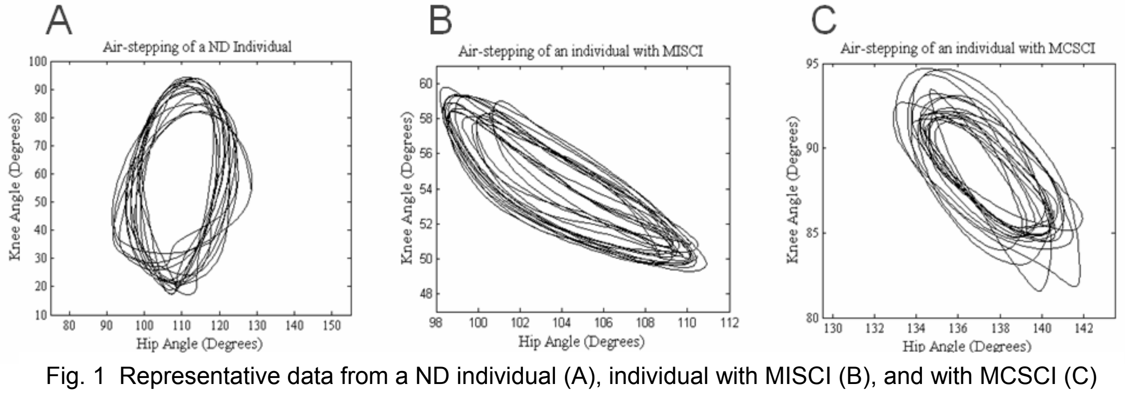

Fig. 1 Representative data from a ND individual (A), individual with MISCI (B), and with MCSCI (C)

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The influence of walking speed on the spatio-temporal parameters of gait in people with Multiple Sclerosis.

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INTRODUCTION: Among tasks of daily living, walking ability is rated as highly important by people with Multiple Sclerosis (MS) and is regarded as a significant factor in determining overall quality of life. Reported changes to walking patterns in mildly impaired persons with MS are often sub-clinical and include slower gait speeds, shorter strides, and longer dual support times at self-paced speeds [1-3]. However, it remains unclear if people with MS are changing their stride parameters solely because of slower gait speed or, the adoption of a "safer" locomotion strategy as a consequence of disease-related disability. This study seeks to directly compare the spatio-temporal gait parameters of people with MS to those without MS at specific gait speeds to explore whether changes in gait patterns are attributable to changes in gait speed or are related to sub-clinical disability.

METHODS: Three people with mild impairment due to MS (Kurtzke Expanded Disability Status Score [EDSS] < 3) and four people without MS serving as controls volunteered for this study. Multiple footfalls were recorded from each participant as they walked barefoot across a 2 x .5 meter instrumented walkway (RSscan International), which was set into the center of an 11.75 m boardwalk. Participants were familiarized with the experimental setup during four initial recorded trials walking at their preferred pace. Participants were then instructed to walk at slow (0.6 m/s); medium (1.0 m/s); and fast (1.4 m/s) speeds until 4 collections that fell within +/-10% of each target speed were collected.

RESULTS: Preferred walking speeds of each group were not significantly different from one another and fell within the targeted gait speeds. All participants were successful in walking at targeted gait speeds. At each of the discrete gait speeds stride length and relative stride time spent in dual support were similar between groups. As gait speed increased, both groups increased stride length (Figure 1A) and decreased dual support time (Figure 1B) in a similar manner.

CONCLUSIONS: These preliminary results suggest that changes in spatio-temporal parameters of gait in minimally impaired persons with MS are principally related to gait speed and not disease-related impairments. People with mild impairment due to MS may therefore adapt their gait patterns to changes in walking speed in a similar fashion to those without MS. Adaptations in stride parameters that contribute to gait velocity may therefore not be a strong indicator of disability in people with mild impairment due to MS.

ACKNOWLEDGEMENTS: funded by the National Multiple Sclerosis Society RG 3974A2/1.

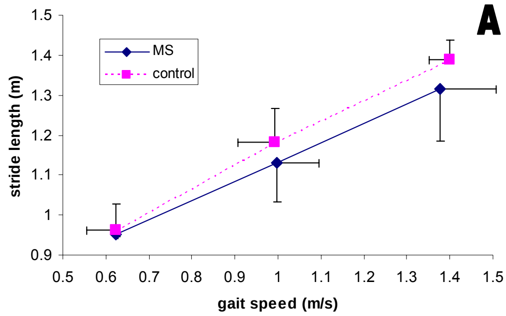

Fig.1A Stride length (m) vs. gait speed (m/s) in people with and without MS.

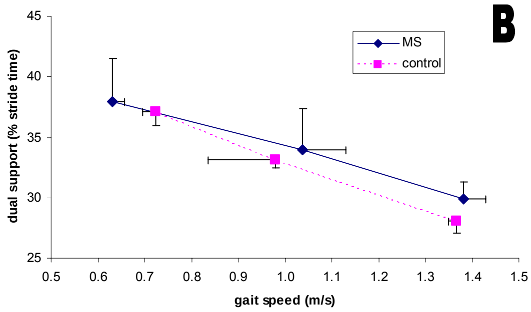

Fig.1B Dual support time (% gait cycle) vs. gait speed in people with and without MS.

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The gait characteristics of people with Frontal Gait Apraxia

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INTRODUCTION: The aim of the study was to investigate the primary gait deficits in people with Frontal Gait Apraxia (FGA) using spatiotemporal measures. FGA is a commonly occurring gait disorder in the elderly of unclear aetiology that is diagnosed from observing the clinical presentation and by eliminating other well defined diseases such as Parkinson's disease [1]. Past studies of FGA have reported limited objective gait data and have not investigated the underlying deficits of this gait disorder.

METHODS: The footstep patterns of 14 participants with FGA were compared to 14 age and sex matched controls using the GAITRite®, which is an electronic walkway system. The gait data of the groups were compared at preferred walking speed and preferred walking speed of the matched participant with FGA. Gait variability, expressed as the coefficient of variability (COV), was compared for the two groups during both test conditions. Participants with FGA were also tested walking at their self selected fast walking speed.

RESULTS: There were 2 females and 12 males in each group. Participants with FGA (average age 83.6 years) walked significantly slower (mean difference -58.8 cm/s, 95% CI -76.9 to -40.8 cm/s, p<0.001), with reduced step length (mean difference -31.6 cm, 95% CI -41.3 to -21.9 cm, p<0.001) and wider step width (mean difference 7.1 cm, 95% CI 4.3 to 9.8 cm, p<0.001) than controls (average age of 82.6) at preferred walking speed. Participants with FGA continued to have shorter steps (mean difference -12.5 cm, 95% CI -23.9 to -1.1 cm, p=0.03), greater cadence (mean difference 33.9 steps/min, 95% CI 22.3 to 45.4 steps/min, p<0.001) and greater step width in the matched speed condition. Variability of walking speed (mean difference 3.5%, p=0.01), cadence (mean difference 1.5%, p=0.005) and step length (mean difference 3.7%, p=0.006) were significantly increased in participants with FGA under the preferred walking speed condition, but there was no difference between groups for variability of gait in the matched speed condition. Participants with FGA increased their walking speed significantly in the fast walking condition, from a mean of 61.7 cm/s to 73.2 cm/s (p<0.001).

CONCLUSIONS: Footstep pattern differences between participants with FGA and healthy elderly were not due to differences in walking speed. Participants with FGA continued to have a slow gait speed when walking fast. These findings suggest people with FGA were not able to regulate their gait speed due to disruption to the regulation of step length or footstep timing or both.

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Relationship between gait and health related quality of life in people with Parkinson's disease

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INTRODUCTION: The aim of the study was to investigate the relationship between gait impairment and health-related quality of life in people with Parkinson's disease (PD). Parkinson's disease is associated with impaired mobility. A decrease in gait speed is an early feature of Parkinson's and freezing of gait may develop as the disorder progresses. Slowness of gait has been found to interfere with a person's ability to perform activities of daily living which may decrease a person's quality of life (QOL). Although past studies have shown that health-related QOL is affected in people with PD, the relationship with gait function has not been examined.

METHODS: Baseline measures of gait speed and health-related QOL were recorded for 66 people with idiopathic PD who participated in a randomised controlled trial investigating the efficacy of physiotherapy interventions in preventing falls and improving mobility. Deficits in walking were quantified using the Timed 6m Walking Test and the Timed Up and Go Test (TUGT) [1]. Health-related QOL was measured using the Parkinson's Disease Questionnaire-39 (PDQ-39) [2]. The relationship between health-related QOL and gait speed, cadence and step length was investigated using Pearson product-moment correlation coefficient. The relationship between health-related QOL and the Timed Up and Go Test was analysed using Spearman rank correlation coefficient.

RESULTS: Participants, 47 males and 19 females had a mean age of 69.39 years (range 47 to 87) and a mean Hoehn and Yahr stage of 2.5 (range 1 to 4). The mean gait speed for participants was 1.15 metres/second (range 0.42 to 1.79m/s), mean cadence was 114.6 steps/minute (range 59.26 to 149.69 steps/min), mean step length was 0.60m (range 0.22 to 0.86m) and the mean TUGT time was 10.8 seconds (range 6 to 28 seconds). The mean PDQ-39 summary index score was 25.5 (range 1 to 62). There was a moderately strong positive linear correlation between health-related QOL and TUGT (rho = 0.33, p = 0.009) and cadence (r = 0.292, p =

0.024) and a negative correlation with step length (r = -0.298, p = 0.021). There was no correlation between health-related QOL and walking speed (r = -0.099, p = 0.452).

CONCLUSIONS: Gait impairment in people with mild to moderate Parkinson's disease may be related to poorer health related QOL. Interventions designed to improve mobility may be useful in improving QOL in people with PD.

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The effects of door width on freezing in Parkinson's disease

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INTRODUCTION: Freezing of gait (FoG) is a locomotor phenomenon exhibited in a subgroup of patients with Parkinson's disease. In FoG a patient comes to an involuntary halt while walking, or cannot start walking despite a desire to do so. FoG commonly occurs in certain environmental conditions, including walking through doorways. We investigated the basis of this effect by measuring the responses of 'freezers' to doorways of varying width.

METHODS: Patients walked from one end of the laboratory to the other in four conditions. In the first condition there was no doorway present. In the other three conditions a doorway was present in the walking path and its width was scaled to the shoulder width of the walker (100%, 125% and 150% shoulder width). The order of presentation of the three door width conditions was randomised between participants.

RESULTS: The freezing phenomenon was sensitive to the presence of a doorway and to its width. In five patients, more freezes occurred with a doorway present than without. The total time spent frozen was inversely proportional to door width (narrower doors caused more freezing) (p = .035). The proportion of trials on which a patient froze also decreased with door width (p = .015). Using a motion capture system we showed that the presence of a doorway affected gait parameters even on trials where no overt freezes occurred. There were decreases in, heel lift, step time and step length in the approach to the doorway. We also assessed the impact of (i) dopaminergic medications and (ii) deep-brain stimulation on these effects. Both treatments were independently effective in most patients and had additive effects in some cases.

CONCLUSIONS: The results show that the freezing phenomenon is highly sensitive to the surrounding environment and suggests an atypical coupling between perceptual input and motor output in patients who freeze. Consistent with recent work, our data imply that freezing results from gradual changes in gait patterns and further reveal the sensitivity of these changes to subtle environmental manipulations such as door width.

ACKNOWLEDGEMENTS: Thanks to Daniel Voyce for engineering support. Funded by MRC Grant G0502136.

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Effects of a multi-mode exercise program on Parkinson's patients gait parameters

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INTRODUCTION: The compromised locomotion is one of the major consequences of Parkinson's disease. The search for effective interventions for improving gait parameters of Parkinson's disease patients has been of great interest of researchers. Some studies have achieved satisfactory results by means of programs that used specific exercises or for locomotion [1-2] or for lower limbs strength [3]. However, little is known about the effects of a multi-mode exercise program (aerobic capacity, flexibility, strength, motor coordination and balance) on the gait parameters of Parkinson's disease patients. The purpose of this study was to identify which gait parameters of patients with idiopathic Parkinson's disease change after participation in a multi-mode exercise program.

METHODS: thirteen PD patients (66.3±7.9 years of age), ranged from Stage 1 to 3 of Hoehn & Yahr scale, participated in the study. The patients' gait parameters were assessed before and after the enrolment in the multi-mode exercise program. During 24 weeks (6 months), 72 sessions, 3 times a week, and 60 minutes for session, patients participated in the program. In order to be included on the data analyses the participant should be present on at least 70% of the sessions at the end of the program. For the kinematic analyses, the patients walked on an 8m pathway in their preferred speed in 5 consecutive trials. All trials were recorded by means of a digital camcorder (JVC, model GVR-DVL 9800) capturing the passive markers attached on the right lateral calcaneus face and the left medial calcaneus face and viewed on the right sagittal plane. Software Dvideow was used for the photogrammetric procedure and the dependent variables were calculated by an algorithm created in MatLab 7.0.

RESULTS: after the patients enrolment in the program, the t paired test revealed a significant increase for stride length (t_{64}= -2.789; p=0.007) and for stride velocity (t_{64}= -2.587; p=0.012). Step length, stride duration and cadence did not change. Table 1 presents these results.

CONCLUSIONS: the multi-mode exercise program was efficient to improve gait parameters of PD patients even though the progressive feature of the disease.

ACKNOWLEDGEMENTS: FAPESP, CNPq, FNS, CAPES.

DEPENDENT VARIABLE	PERIOD	
	Pre	Post
Step length (m)	0,50 (± 0,05)	0,50 (± 0,06)
Stride length (m)	1,02 (± 0,10)	1,05 (± 0,12)*
Stride duration (s)	0,98 (± 0,07)	0,97 (± 0,07)
Stride velocity (m/s)	1,05 (± 0,12)	1,08 (± 0,12)*
Cadence (stride/s)	1,03 (± 0,08)	1,04 (± 0,07)

Table 1. Means and standard deviations of the gait dependent variables. * Significant difference (p<0.05) between pre- and post-intervention

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P.277

Reduced performance in balance, walking and turning tasks might be related to increased neck tone in Parkinson's disease

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INTRODUCTION: Rigidity (or muscle hypertonicity), defined as an increased resistance to passive movement, is one of the cardinal symptoms of Parkinson's disease (PD). It has been suggested that rigidity may underlie many of the common motor disabilities associated with PD [1]. We hypothesized that axial hypertonicity affects functional performance in tasks involving balance, walking and turning.

METHODS: The magnitude of axial postural tone in the neck, trunk and hip segments in 15 subjects with PD (both ON and OFF levodopa) and 15 control subjects were correlated to their performance on six functional tests (Figure of Eight, Timed Up & Go, Berg Balance Scale, Roll-over, a supine rolling task, Functional Reach and a Standing 360 deg turn-in-place). Axial tone was quantified using a unique device developed in our laboratory [1,2]. Subjects stood quietly on a rotating platform while their upper body was fixated at three different heights to quantify resistance to axial twisting in the neck, trunk and hips. The lower segment was slowly rotated in the yaw axis (±10 deg at 1deg/s), shown at the bottom of Fig. 1A) while tone (resistance to slow rotation) was measured in the lower segment (see example raw trace in Fig. 1A).

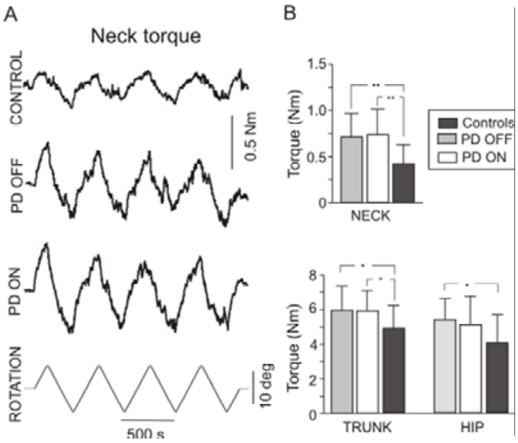

Fig.1. A) Representative raw data. B) Resistance to axial twisting (mean + SD) at the neck, trunk and hip in all groups. ** denotes p<0.01 and *denotes p<0.05

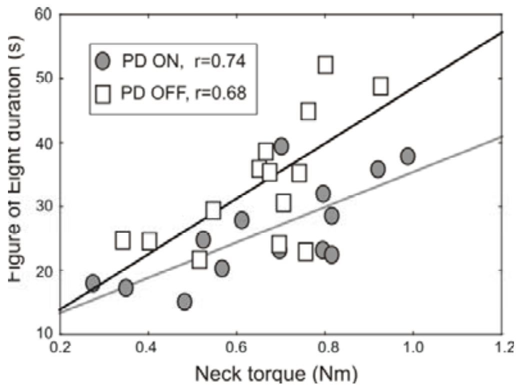

Fig.2. Relation between the neck torque and the Figure of Eight in PD ON and OFF. Regression lines are shown for the PD's OFF (black) and ON (grey) medication

RESULTS: As seen in Fig. 1B, we found that subjects with PD have increased axial tone in all segments compared to controls (p=0.008) and that this increase was most prominent in the neck. Levodopa did not affect axial tone in any of the segments (p>0.05). The neck tone was most strongly related to the functional performance tests in PDs and accounted for a considerable proportion of the variability in the performance of the Figure of Eight test (r_{OFF}=0.68 and r_{ON}=0.74, p<0.05, see Fig. 2) and the Roll-over test (r_{OFF}=0.67and r_{ON}=0.55, p<0.05).

Conclusions: These findings suggest that neck tone plays a significant role in functional mobility and that high postural tone may be an important contributor to balance and mobility disorders in individuals with PD.

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Association among gait initiation after sit-to-stand and functional capacity components in Parkinson's disease

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Introduction: Sit-to-stand and gait initiation are necessary tasks to live independently [2,4]. Adequate levels of function capacity [1] are required to performance these tasks and 80% of Parkinson's disease (PD) patients reported difficulty on it [4]. The purpose of this study was to analyze the association among gait initiation parameters after rising from a chair with the functional capacity components in PD patients.

Methods: 23 idiopathic PD patients participated in the study (66.6±7.6 years of age; Stages 1 to 3 on Hoehn &Yahr; 33.4±15.9 UPDRS points). The tests were performed on three different days and in a random order: a) clinical assessment done by a neurologist; b) functional capacity – aerobic resistance, flexibility, coordination, strength and dynamic balance by means of AAHPERD tests and functional balance by means of Berg scale [3]; c) sit-to-stand and gait initiation task – rising from a chair (46.5 cm of height) and to walk on a 3m wide rubberized walkway. Each participant performed 3 trails in their maximal velocity. The participants' behaviors were recorded, in the sagittal plane, by a digital camcorder with 60-Hz field rate. The following dependent variables were analyzed in the first stride after to stand of the chair: step length (SEL) and duration (SED), stride length (SIL) and duration (SID), and speed (VEL). The Pearson correlation was used to verify the relationship between spatial-temporal variables and functional capacity components (p<0.05).

Results: The spatial-temporal variables show high relationship with functional capacity components (balance, agility, strength and resistance; Table 1).

Conclusions: High level of strength, balance, agility and resistance are associated with the performance of sit-to-stand and gait initiation task, preventing the muscle mass reduction. Good level of functional capacity can reduce instability [2] and slowness [1] caused by the aging process and the Parkinson's disease [4].

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		SEL (m)	SED (m)	SIL (m)	SID (m)	VEL (m/s)
mean±s		0.40±0.10	0.34±0.04	0.93±0.22	0.87±0.13	1.14±0.27
52.18±4.39	**balance (pt)**	0.73 +	0.08	0.37	-0.52 *	0.71 +
52.44±13.57	**flexibility (cm)**	0.20	0.16	0.13	-0.03	0.14
17.61±7.55	**coordination (s)**	-0.54 +	-0.13	-0.07	0.36	-0.40
30.90±13.13	**agility (s)**	-0.66 +	0.21	-0.50 *	0.81 +	-0.92 +
20.76±5.13	**strength (rep)**	0.63 +	-0.04	0.04	-0.34	0.46 *
9.70±2.88	**resistance (min)**	-0.57 *	0.12	-0.39	0.54 *	-0.76 +

Table 1. Means and standard deviations values of the spatial-temporal variables and functional capacity components, and the Pearson correlation values.* p<0.05; + p<0.001

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Sensorimotor, balance and gait risk factors for falls in Parkinson's disease

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INTRODUCTION: Falls are common in older people with Parkinson's disease (PD), and are likely to be related to strength, balance and gait disturbances associated with this condition. Although several studies have identified some clinical measures and have evaluated differences in basic gait parameters in people with PD, none have directly evaluated the stability of the upper body during gait or quantitatively assessed physiological impairments in this group. The purpose of this study was to (i) examine upper body stability during gait, and (ii) devise a physiological fall risk assessment for guiding fall prevention interventions.

METHODS: 113 people with PD (age 66 ± 95%CI 1.6 years) underwent clinical assessments and quantitative tests of sway, gait, strength, reaction time and lower limb sensation. Participants were then followed up for 12 months to determine fall incidence. Spatiotemporal gait parameters and acceleration patterns at the head and pelvis were also measured with triaxial accelerometers in a subset of 66 participants - 33 with a history of falls (mean age 67 ± 2 years) and 33 with no history of falls (mean age 63 ± 4 years) at assessment. Harmonic ratios (HRs) of head and pelvis accelerations in each plane were calculated to provide indicators gait rhythmicity and upper body stability.

RESULTS: In the follow-up year, 51 participants (45%) fell one or more times while 62 participants (55%) did not fall. A multivariate model combining clinical and physiological measures that elucidate the pathophysiology of falls identified abnormal posture, freezing of gait, frontal impairment, poor leaning balance and leg weakness as independent risk factors. This model correctly classified 39/51 fallers (77%) and 51/62 non-fallers (82%). In the 66 participants who underwent the gait assessments, PD fallers exhibited poorer HRs in all three planes at the head and pelvis. The differences between the fallers and non-fallers remained significant for the pelvis in the vertical and antero-posterior planes after adjusting for walking speed and step timing variability.

CONCLUSIONS: Patients with PD at risk of falls can be identified with a high degree of accuracy with PD-specific clinical measures and quantitative physiological tests. The gait accelerometry analysis also suggests that an inability to control displacements of the torso when walking may predispose older people with PD to falls. Taken together, these findings identify a range of fall risk factors that are amenable to targeted intervention.

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Turning problems in Parkinson patients with freezing of gait: preliminary data

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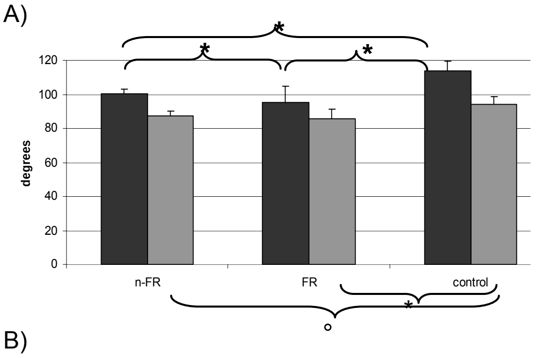
INTRODUCTION: Turning in patients with Parkinson's Disease (PD) is the most important trigger for Freezing of gait (FOG) [1] which has a major impact on Quality of Life. Although turning problems and the head-trunk relation during turning were recently investigated in PD [2-3], these differences were not compared between freezers (FR) and non-freezers (n-FR).

METHODS: 16 patients with PD (7 FR and 9 n-FR, matched for disease severity) in the off-period of the medication cycle and 10 age-matched controls were asked to turn 180° to the right. A 9 camera VICON three-dimensional motion analysis system was used to measure head- and trunk angle compared to the laboratory axes on 3 different moments: start of the turn, turning point of COM (Centre of Mass) and the end of the turn. The turning cycle was then divided into two phases defined by the COM turning point. The results were averaged over 3 trials for each person.

A)



B)

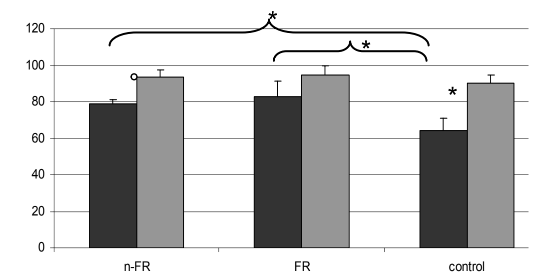


Fig. 1 The amount of turning degrees for freezers (FR), non-freezers (n-FR) and controls during phase I=fig. A and phase II= fig. B of a 180°turn to the right. black=head, grey=trunk. *=p<0.01, °=p<0.05

RESULTS: No significant differences were found between freezers and non-freezers for H&Y stages and UPDRS III. Repeated measures ANOVA revealed a significant interaction effect (group*phase*body) of p=0.04. In contrast to Frs, n-FRs and controls turned their head more in the first phase than the second phase (turning back) of the turning cycle (p<0.01). Controls rotated their head significantly more than n-FRs (p<.01) during the first phase, who in turn rotated their head significantly more than FRs (p< 0.01). The opposite was found for the second phase, where a trend was seen between FRs and n-FRs of p=0.07 (fig. A and B). Overall, the trunk rotated more in controls than in patients during the first phase (p<0.01).Also during the first phase, controls turned their head relatively more than their trunk (p<0.01). On the contrary, during the second phase non-freezers and controls turned their trunk relatively more than their head (p<0.05-0.01). Freezers showed no significant differences between head and trunk movements (fig. A and B).

CONCLUSIONS: These preliminary data reveal a difference between the turning behavior of FRs and n-FRs. These results indicate that FRs use an ‘en-bloc’ strategy to a greater degree during a 180°turn, which cannot be explained by greater disease severity.

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Objective detection of freezing of gait elicited by obstacle avoidance during treadmill walking in Parkinson’s disease

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INTRODUCTION: Freezing of gait (FOG) is a clinically defined phenomenon of Parkinson’s disease (PD). Detailed electrophysiological studies of the underlying pathophysiology are difficult, because FOG is notoriously difficult to elicit in the gait laboratory. However, recent work showed that obstacle avoidance during treadmill walking can elicit subtle FOG episodes. Our objective was to evaluate which quantitative gait parameters identify subtle FOG episodes.

METHODS: We included 10 patients with PD and clinically certified ‘OFF-state’ FOG. Patients were tested in a practically defined OFF condition. Patients were asked to walk on a motorised treadmill and to avoid unexpectedly appearing obstacles. FOG episodes during treadmill walking were defined based upon review of videotaped gait performance by two independent experts. Gait was also analysed using detailed kinematics, and knee joint signals were processed using time-frequency analysis with combinations of sliding Fast Fourier transform (FFT) and wavelets transform.

RESULTS: 20 FOG episodes occurred during treadmill walking in five patients, predominantly in relation to obstacle avoidance. FOG occurred mainly just before or after obstacle crossing and was characterised by short rapid steps. Frequency analysis showed an increase in power in the 3-8 Hz band (2) and a decreased power in 0-3 Hz (3) band during the FOG episode, and was preceded by an increase in dominant frequency in the 0-3 Hz band (1, festination FSG), see Fig.1.

CONCLUSION: Obstacle avoidance provokes subtle FOG episodes during treadmill walking. Time frequency analysis is an appropriate approach to analyse biomechanical gait signals. This approach can reliably detect even subtle FOG episodes, possibly even beyond those detectable by expert clinicians. Therefore these methods invite further studies aimed at better understanding and describing the underlying pathophysiology of PD FOG. These methods detected FOG with acceptable sensitivity (79%) and specificity (94%).

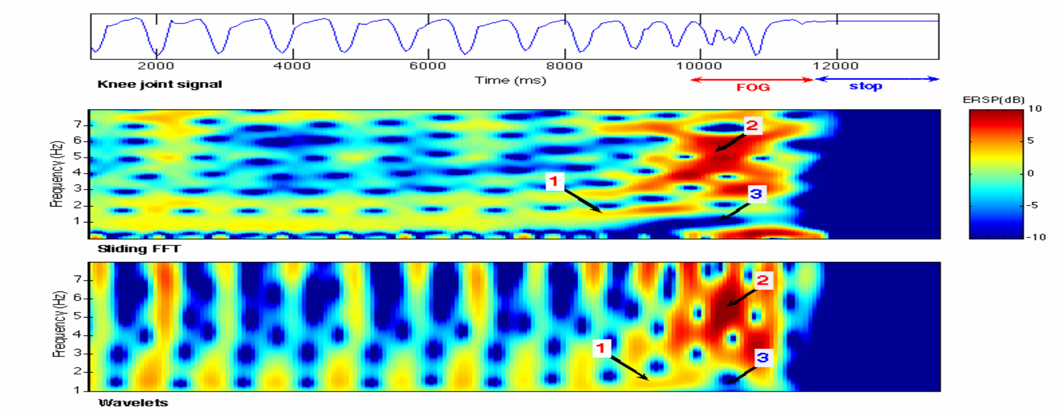

Fig. 1

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The impact of deep brain stimulation on parkinsonian gait during dual tasking

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INTRODUCTION: Subthalamic deep brain stimulation (DBS) relieves many of the motor symptoms associated with Parkinson's disease (PD) including certain aspects of gait (e.g., gait speed). Still, the effects of DBS on gait and fall risk have not been fully described. In fact, some have suggested that fall risk actually increases in response to DBS. One possibility is that DBS exacerbates cognitive impairment and this is turn exacerbates the effects of "dual tasking" on gait, increasing fall risk post-DBS. To address this question and gain insight into the impact of DBS in general and the subthalamic nucleus, in particular, on gait and fall risk, we evaluated the impact of DBS on the quality and speed of gait in patients with PD who underwent DBS surgery and compared walking with the stimulation (on stim) to walking without stimulation (off stim), under two different dual task (DT) conditions.

METHODS: 35 patients with PD with DBS implants (mean age: 63.2±8.5 yrs; 6 women; mean time since surgery: 24.7±12.4 months; mean disease duration: 13.6±5.8 yrs; mean UPDRS-motor when off stim and off meds: 39.3±13.2) walked under 4 conditions: off meds/off stim, off meds/on stim, on meds/off stim, and on meds/on stim. In each condition, they performed 3 walking tasks, for 1 minute each while wearing force-sensitive insoles: 1) usual-walking (single task), 2) while subtracting serial 3`s (S3), and 3) while generating word lists (verbal fluency, VF). Gait speed, Drag percent (Dpct), a measure of the percent of time spent with one foot on the ground, averaged for left and right, and Drag percent variability (DpctCV), were calculated. These latter two measures reflect the classic stance percent and stance percent CV measures, but due to the problematic quality of the walking pattern (e.g., shuffling), they were extracted from a constant window (1 sec) and not from stride cycles per se.

RESULTS: EFFECTS OF DUAL TASK: In general, S3 and VF reduced gait speed and increased Dpct and DpctCV under all med / stim conditions. For example, off meds / off stim, gait speed was reduced from 0.91±0.37 m/sec to 0.73±0.36 m/sec during S3 (P<0.001). EFFECTS OF DBS WHILE OFF MEDICATIONS: DBS significantly increased gait speed (p<0.01) during the three walking tasks (single task and two dual task), compared to the no stim condition. Dpct also significantly decreased during usual-walking (from 71.7±7.4% to 68.6±4.1%, p<0.003) and during S3 (from 73.2±7.2% to 69.9±5.2% p<0.0004), but not during VF, in response to DBS. DpctCV did not significantly change in response to DBS. EFFECTS OF DBS WHILE ON MEDICATIONS: Although the UPDRS-motor scores improved in response to DBS (from 37.1±14.6 to 16.6±11.4; p<0.000), gait speed, Dpct and DpctCV did not change significantly in response to DBS during the three walking tasks (single and two dual tasks), compared to the values observed for the same tasks in the on meds, off DBS condition. EFFECTS OF DBS ON THE DIFFERENCE BETWEEN USUAL-WALKING AND DT WALKING: there were no significant changes in the dual task decrement in gait speed, Dpct, or DpctCV, while off or on meds. For example, gait speed declined by 0.20±0.15 m/sec in response to S3 while on meds/ off stim and by 0.22±0.11 m/sec while on meds/ on stim (p=0.55).

CONCLUSIONS: Consistent with previous findings, we observed that DBS generally enhances motor function and gait speed, especially when anti-parkinsonian medications are withheld. However, in the present of medications, DBS was generally less effective. Moreover, the present findings demonstrate that DBS does not alter the dual tasking effects on gait. Thus, one could suggest that patients with PD tend to walk faster with DBS, but with a similar unfavourable response to dual tasking. Perhaps this creates an especially unsafe situation and explains why patients with DBS have an increased fall risk.

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Relationship between the angular amplitude oscillation and gait parameters during obstacle avoidance in Parkinson's disease

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INTRODUCTION: The independent locomotion permits the subject to interact with the environment. So, the subject must have to adapt the gait pattern according to the land complexity. This task is one of the major problems in Parkinson's disease (PD) patients [1]. Several studies have been present the typical PD walking pattern: reduced velocity, increased stance phase and decreased stride length [2]. Furthermore, an obstacle on the travel path can be considered a challenge task for these patients [3]. As a result, the postural stability has to be controlled to achieve the task successfully. However, the PD is characterized by postural instability and falls [4]. So, the aim of this study was to investigate the relationship between the angular amplitude oscillation and gait parameters during obstacle avoidance in PD.

METHODS: 12 idiopathic PD patients participated in this study (66.7 ±7.8 years of age; Stages 1 to 3 Hoehn & Yahr; 31.5 ±13.4 UPDRS points). The tests were performed in three consecutive days: 1) clinical assessment done by a neurologist; 2) gait analysis during obstacle avoidance (high obstacle at half of knee height; low obstacle at ankle height); 3) postural tasks (to maintain the upright stance). The participant's behaviors were recorded, in the sagittal plane for the gait tasks and sagittal and frontal planes for the postural tasks, by a digital camcorder with 60-Hz field rate. For the gait and postural tasks, the dependent variables were, respectively: leading toe clearance (LTCL) and angular amplitude oscillation in two directions: anterior/posterior (AAOAP) and medio/lateral (AAOML). The Pearson correlation was used to verify the relationship between the LTCL and AAO (both direction) ($p<0.05$).

RESULTS: The LTCL (high obstacle) variable showed high relationship with AAOAP ($r=0.68$, $p=0.028$). Besides, the LTCL (low obstacle) variable showed high relationship with AAOML ($r=0.71$, $p=0.021$).

CONCLUSIONS: Based on these results, the increase of LTCL is strongly associated with the increase of AAOAP and AAOML. One of possible explanation is that the PD patient rise the leg greatest to avoid the high obstacle and this compensation occurred in the anterior-posterior direction. Differently, to clear the low obstacle the compensation occurred in the medio-lateral direction. So, to perform the most challenge task, the PD patients control the body balance in the antero-posterior direction. On the other hand, to perform tasks that not threaten the body balance, they control the body balance in the medio-lateral direction. In this context, the balance control could be impaired as a consequence of their large body oscillation. However, to accomplish these tasks, the PD patients were capable to avoid the obstacle showing that they do not have a rigid system.

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Disturbances in gait and interlimb coordination in Parkinson's disease patients with freezing of gait

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INTRODUCTION: Freezing of gait (FOG) is a common and disabling gait disturbance in Parkinson's disease (PD), with episodes during which patients experience a sudden inability to start walking or to continue moving forward [1]. Previous studies have found a higher asymmetry [2] and variability of gait [3] in PD patients with FOG compared to those without FOG. Arm movements and coordination between the upper and lower limbs were not examined in these gait studies, but it is known that these features are disturbed for PD patients in general [4]. We examined whether PD patients with FOG exhibit disturbances in arm swing, stride length regulation and interlimb coordination (between the upper and lower limbs) more than PD patients without FOG and control subjects.

METHODS: We included three groups: 13 PD patients with subjective "off" period FOG (PD+FOG), 15 PD patients without FOG (PD-FOG) and 15 healthy age- and gender-matched controls. Patients from both groups were matched for disease severity. Subjects walked over ground (at their preferred speed, and while walking as fast as possible; each six times for 6 meters) and on a treadmill (at 1.5 km/h, 2 km/h, 3 km/h, and at their preferred speed; 1 minute for each velocity). Kinematic gait parameters were measured with a motion analysis system (VICON). Outcome measures included duration, length, asymmetry in length, and variability (coefficient of variation) of arm swing and strides. Interlimb coordination was assessed as the delay in time between the heel strike on one side and the maximal forward arm swing on the contralateral side, calculated as a percentage of the gait cycle. Differences between groups were compared using a one-way ANOVA, with 'group' as between-subject factor. A Tukey's post-hoc test was conducted, corrected for multiple comparisons ($p < 0.05$ as significance level).

RESULTS: There were no group differences in duration and asymmetry of arm swing and strides. During both over ground and treadmill walking, arm swing amplitude and stride length were smaller in PD patients than in controls, and variability of arm swing and strides was higher. Stride length was smaller for the PD+FOG group compared to PD-FOG in the treadmill conditions, and stride length variability was higher. For example, at 3 km/h, stride length was 14 cm smaller ($p=0.047$) and stride length variability was 17% higher ($p=0.046$) in the PD+FOG group. Interlimb coordination between the upper and the lower limbs was less synchronized in patients compared to controls (i.e. showed a larger delay). When the coordination between the affected arm and the less affected leg was compared during for fast over ground walking, there was a significant difference between PD-FOG and PD+FOG (2.16 times worse in PD+FOG, $p=0.03$). For the other conditions, no significant differences between the two patient groups were found.

CONCLUSIONS: Although stride length regulation (length and variability) is affected by FOG, arm swing and coordination between upper and lower limbs is not. Hence, FOG appears to be caused by a defect in regulation of leg movements, but not in arm movement regulation or the coordination between upper and lower limbs.

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Impaired bilateral coordination of gait and upper extremity rhythmic movements in Parkinson's disease: association with freezing of gait

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INTRODUCTION: Recent studies indicate that bilateral coordination of gait is impaired in patients with Parkinson's disease (PD) and that this impairment may be related to the freezing of gait (FOG) phenomenon seen among advanced PD patients. The objective of the current work is to study the hypothesis that PD patients with FOG (PD+FOG) have a generalized deficiency in the bilateral coordination of rhythmic movements.

METHODS: 19 PD+FOG patients, 11 PD patients without freezing (PD-FOG) and 16 elderly subjects (Table 1) were tested during the "OFF" stages of the medication cycle (i.e., > 12 without levodopa intake). Bilateral coordination of gait was assessed during a 100 m straight line walk performed at a self-selected, comfortable pace. To determine the timing of the gait cycle, subjects walked while wearing force sensitive insoles. We defined the stride duration of one foot as a gait cycle or 360°, determined the relative timing of contra-lateral heel-strikes, and defined this as the phase, φ (ideally, φ=180° for every step). The sum of the coefficient of variation of φ (φ_CV) and the mean absolute difference between φ and 180° (φ_ABS) was defined as the Phase Coordination Index (PCI), representing variability and inaccuracy, respectively, in phase generation. Subsequently, the subjects sat in front of a flat board in which two force sensitive rectangles (one for each hand) were embedded. They were asked to perform left-right alternating tapping on the rectangles, for one minute at their comfortable pace, as if they were "walking with there hands." PCI values were calculated for hand tapping using the inter tap interval (ITI) instead of the stride duration.

RESULTS: PD+FOG patients had more errors (i.e., disruption in the alternating pattern) than PD-FOG in producing the alternating, hand tapping pattern

Demographic & Clinical Parameters	**PD+FOG (n=19)**	**PD-FOG (n=11)**	**Elderly (n=16)**
Age (y)	64.3 ± 8.5 (p=0.83)†	65.1 ± 9.6 (p=0.93)‡	64.7 ± 9.1
Gender (F/M)	6/13	6/5	13/3
PD duration (y)	10.7 ± 5.9 (p=0.26)	8.5 ± 4.5 (NA)	-
Hoehn and Yahr Scale	3.1 ± 0.7 (p=0.02)	2.5 ± 0.4 (NA)	-
UPDRS part III	41.5 ± 12.0 (p=0.05)	31.9 ± 11.4 (p<0.001)	2.6 ± 1.4
Coordination Parameters			
Errors: hand tapping (%)	3.9 ± 5.3 (p=0.02)	0.7 ± 1.5 (p=0.18)	0 ± 0
PCI hand tapping (%)	29.8 ± 21.8 (p=0.52)	24.6 ± 19.3 (p=0.02)	11.0 ± 6.6
PCI gait (%)	9.7 ± 5.6 (p=0.08)	6.9 ± 3.2 (p=0.003)	3.7 ± 1.2
Hand tapping CV (%)	17.6 ± 11.0 (p=0.27)	13.1 ± 8.4 (p=0.001)	5.0 ± 1.9
Gait CV (%)	6.3 ± 4.8 (p=0.04)	3.1 ± 1.4 (p=0.02)	2.2 ± 0.6
† and ‡p-values based on ttest comparison between PD+FOG and PD-FOG and between PD-FOG and healthy elderly, respectively; UPDRS- Unified Parkinson's Disease Rating Scale; CV- coefficient of variation of the stride/ITI time, i.e., variability.			

Table 1: Demographic, clinical and bilateral coordination parameters (mean ± SD)

(Table 1). PCI values for alternating hand tapping were increased (reduced coordination) among PD patients as compared to elderly subjects (p=0.005), with no significant distinction between the PD+FOG and PD-FOG groups. Gait PCI and variability were increased in PD+FOG as compared to PD-FOG, but hand tapping variability was not.

CONCLUSIONS: Regardless of FOG status, PD patients have difficulties maintaining an alternating pattern of hand tapping. However, patients with FOG make more errors during hand tapping, compared to non-freezers. PCI values of hand tapping also tend to be higher among PD+FOG patients, compared to non-freezers, however, in contrast to gait, these are not significantly different. While further research is required to differentiate the effects of disease severity, the present findings suggest that walking places unique demands on the bilateral coordination among patients with FOG.

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Improving gait and reducing falls in Parkinson's: protocol for a randomised controlled trial

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INTRODUCTION: Parkinson's disease (PD) is a chronic and progressive neurological condition characterised by gait disorders, postural instability and, in the latter stages, falls [1,2]. Although gait rehabilitation and falls prevention programs are frequently provided for people with PD, there have been few randomised controlled clinical trials (RCTs) to compare the outcomes of movement strategy training, progressive resistance strength training or falls education. The effects of these interventions on falls, gait impairments, disability and health related quality of life (HQOL) in people with stages I-IV PD awaits evaluation. This RCT will evaluate therapy efficacy as well as cost-effectiveness of three different rehabilitation interventions [3].

METHODS: At least 180 people with PD who live in Melbourne Australia will be randomised to one of three groups to receive movement strategy training, progressive resistance strength training or a life-skills program (control group). Patients will attend an outpatient therapy service once per week for 8 weeks as well as completing a home program during that time. Falls frequency and injuries will be recorded over a 14 month period using a patient calendar and falls telephone hotline. Gait, balance, disability and HQOL will be quantified by blinded assessors using the 6m walk test, Timed Up and Go test, shoulder tug, UPDRS, PDQ39 and EuroQOL. Health care costs will also be determined as part of a concurrent economic evaluation.

RESULTS: Recruitment commenced in September 2006 and 180 participants have been randomised across the three groups to date. The three therapy programs were found to be feasible and were well attended and the home programs were closely adhered to by the majority of participants. Twelve month falls data is still being collected for some participants. The trend so far indicates a high falls frequency in this sample, with over 60% of people with PD experiencing falls within the 14 month trial period. Gait disorders were common, particularly in those with more advanced disease. Between-groups differences in falls, impairments, disability and QOL are currently under evaluation. Each therapy program was found to be feasible in terms of delivery.

CONCLUSIONS: Community based outpatient therapy programs provide a viable method of service delivery for people with mild and moderately severe PD. People with PD have a high probability of incurring one or more falls in a 14 month period and most have gait disorders of varying level of severity.

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Interlimb coordination in Parkinson's disease during split belt locomotion

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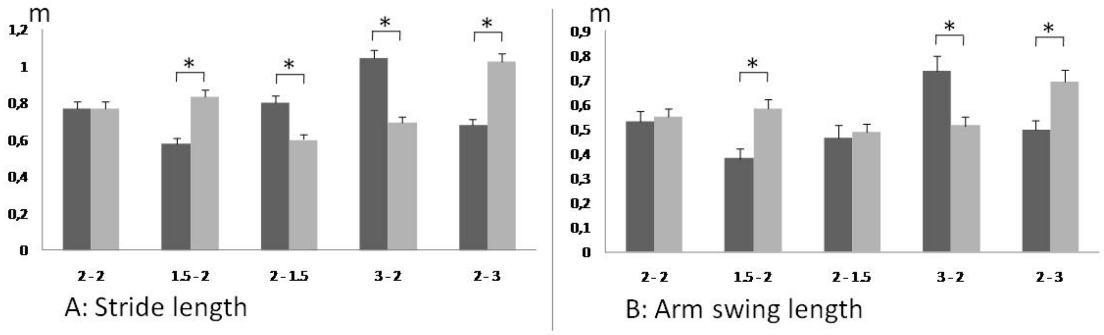

Figure 1: Changes in spatiotemporal characteristics in different split belt conditions

Conditions x-axis: belt speed in km/h on the most affected – less affected side.
With Standard Errors of the Mean. * = significant difference between the legs, p < 0.01

INTRODUCTION: Gait asymmetry and stride-to-stride variability are factors associated with gait disturbances and freezing of gait in Parkinson's disease (PD) [1-3]. A split belt can be used to artificially generate stride length asymmetry [4]. We studied interlimb coordination, asymmetry of arm and leg motion, and stride time variability during split belt locomotion in PD.

METHODS: 15 PD patients (8 with freezing of gait) walked on a split belt at different speeds and with variable differences in speed between both legs (velocity belt most affected side –less affected side: 2-2 km/h, 1.5-2 km/h, 2-1.5 km/h, 3-2 km/h, 2-3 km/h). This was recorded using a video motion analysis system for off-line computation of spatio-temporal gait parameters and synchronization between the arms and legs. Differences were assessed using a repeated measures ANOVA with within-subjects factor 'Condition' and between-subject factor 'Group' (to distinguish freezers from non-freezers). Differences between conditions were then assessed using Wilcoxon signed rank test.

RESULTS: PD subjects were able to adapt to split belt walking by modulating stride length, while keeping a constant stride duration. The arm swing also changed in length, which was generally linked to the change in ipsilateral stride length (Figure 1. ANOVA effect 'condition' $F = 10.1$, $p=0.002$ for arm swing length, $F = 46.3$, $p < 0.001$ for stride length). However, split belt locomotion did not affect stride time variability or arm-leg synchronization. There was no difference between freezers and non-freezers for any of the parameters. There was no freezing of gait during the split belt walking in freezers.

CONCLUSIONS: We used split belt walking in patients with PD to generate an asymmetry in stride length. The arm swing length reacted mostly the same way as the ipsilateral stride length. This artificially generated gait asymmetry had no effect on stride time variability, nor did it influence the synchronization between hands and feet. As split belt walking induces only spatial asymmetry and does not increase stride-to-stride variability, we propose that the split belt can be used for training gait flexibility. Another implication is that split belt walking is unlikely to induce freezing of gait.

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Gait in patients with scans without evidence of dopaminergic deficit (swedds): comparison with Parkinson's disease and healthy controls

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INTRODUCTION: About 10-15 percent of patients thought to have Parkinson's disease (PD) turn out to have normal dopaminergic function based on imaging. The diagnosis in these patients remains unclear and they have been referred to as SWEDDs (Scans without evidence of dopaminergic deficit) [1]. To help further understanding of the pathophysiology of SWEDDs, particularly its distinction from PD, we have performed a preliminary comparison of the gait of SWEDDs patients with PD patients and healthy controls.

METHODS: 6 SWEDDs patients (mean age = 74), 7 PD patients (mean age = 71), and 8 healthy controls (HC; mean age = 72) walked up and down an 8 m walkway at a self-selected, comfortable speed several times whilst whole body movements were tracked using infrared emitting diodes. Patients had been off medication for at least 12 hours. Results are in the form mean ± SD.

RESULTS: Walking speed (m/s) tended to be lower in the patient groups, but the differences were not statistically significant (HC 1.00 ± 0.20, PD 0.92 ± 0.16, SWEDDs 0.82 ± 0.33). An increase in average anterior trunk tilt and elbow flexion were present in the PD group ($p < .05$, relative to HC) but not present in the SWEDDs group. Normalized arm swing, summarized as shoulder flexion/extension motion divided by hip flexion/extension motion, was lower in both PD (0.29 ± 0.11) and SWEDDs (0.32 ± 0.11) than in HC (0.48 ± 0.15) on the side of smallest arm swing ($p <. 05$).

CONCLUSIONS: Our preliminary results indicate SWEDDs patients tend to exhibit arm swing dysfunction but not the flexed posture of Parkinsonian gait.

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Ambulatory monitoring of freezing of gait in Parkinson's disease and normal pressure hydrocephalus

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INTRODUCTION: Freezing of gait (FOG) is common in advanced Parkinson's disease (PD), is resistant to treatment and negatively impacts quality of life. We have developed and validated an ankle-mounted gait monitor [1,2] for detection of FOG events in PD [3], utilizing the frequency characteristics of vertical acceleration of the shank. The aim of this study was to determine whether FOG events in NPH patients exhibit similar movement characteristics as observed in PD patients.

METHODS: Vertical linear acceleration of the left shank during ambulation was sampled at 100 Hz using an ankle-mounted sensor array that stored data on a SD card. Simultaneous video records were obtained throughout testing and FOG events identified by a movement disorders specialist.

RESULTS: Acceleration data from 51 FOG events were obtained from 11 PD patients and 2 NPH patients. Frequency analysis showed high-frequency components of leg movement during FOG in the 3-8 Hz band (Fig. 1B,C) that were not apparent during volitional standing (Fig. 1A). A freeze index (FI) was defined as the power in the 'freeze' band divided by the power in the 'locomotor' band (0.5 – 3 Hz), and a threshold chosen such that FI values above this limit were designated as FOG. Individual calibration of the freeze threshold correctly identified 90% of FOG events in PD patients, with 10% false positives [3]. Preliminary data from NPH patients (Fig. 1C) demonstrated similar frequency characteristics of vertical leg motion during FOG.

CONCLUSIONS: FOG is currently resistant to treatment and there is no means to identify FOG events. Ambulatory monitoring may significantly improve clinical management of FOG in PD and NPH by providing an objective assessment of treatment efficacy.

ACKNOWLEDGEMENTS: Supported by NIH/NINDS grant R41 NS059086-01A1 and NASA grant NNJ04HF51G.

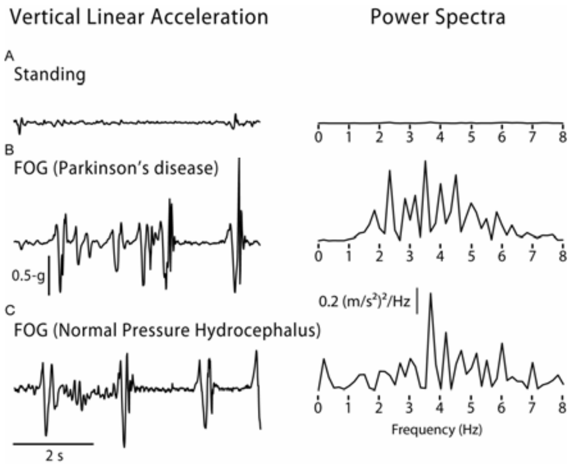

Fig.1 Vertical linear acceleration of the left shank (left column) and power spectra (right column) ***A*** when quietly standing, ***B*** FOG during gait initiation in a patient with PD, and ***C*** FOG during gait initiation in a patient with NPH.

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Feasibility of using the Lokomat robotic system for patients with Parkinson disease

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INTRODUCTION: Gait disturbance in patients with Parkinson disease (PD) is the major factor affecting quality of their life. Although addressed by conventional rehabilitation, gait training might benefit from the use of innovative robot-assisted device Lokomat. To test this hypothesis fesibility of the using the Lokomat robotic system in patients with PD was analyzed.

METHODS: Ten patients (4 women, 6 men) with akineticorigid and rigid-tremor form of PD, age 35-65 years, Hoehn and Yahr stage 3-4 practiced walking with the robot-assisted Lokomat system. Vertical body weight unloading 35.6±3.7 % and unexpected changes of treadmill speed (from 1.2 to 1.9 km/h) were applied during training sessions lasting from 15-21 to 40-45 min. The values of vertical and horizontal (up to 5% - 0%) weight unloading had been gradually decreased over time. The training course included 10-15 sessions. Clinical evaluation of patients was done using the 42 items UPDRS scale before and after practice with specific attention to the items 22 (stiffness), 29 (gait), 31 (body bradikinesia/hypokinesia), test of 20-m walking. Gait kinematic was assessed using magnetic system for motion analysis “Flock of birds”.

RESULTS: After course of Lokomat therapy significant improvement of most measured variables was observed including bradykinesia decrease of 41.0%, stiffness – of 22.9%, walking speed increase of 30.6%. Therefore, upon completion the Lokomat therapy, participants demonstrated increased step length and reduced time to make a 180º turn.

CONCLUSIONS: the results showed that robot-assisted gait therapy with the Lokomat system can be used in rehabilitation of patients with PD. Further studies are needed to assess the effect of Lokomat therapy on the gait of patients with PD.

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Long term follow up of advanced Parkinson’s disease following STN deep brain stimulation: impact on gait, balance and functional activity

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INTRODUCTION: A recent randomised long-term assessment of surgery for Parkinson’s disease (PD) (PD SURG) evaluated the efficacy of deep brain stimulation of the sub-thalamic nucleus (DBS-STN), compared to medical therapy in patients with advanced PD and demonstrated significant improvements in quality of life. This study aimed to quantify changes in severity of motor symptoms associated with gait after DBS-STN compared to objective measures of gait performance and function. We carried out a long term evaluation of gait, balance and functional activity following DBS-STN.

METHODS: 18 people with PD were recruited. Activity was measured 6 months (P3) and 6 weeks before surgery (P4) and at four time points after surgery (6 weeks (T1), 3 months (T2), 6 months (T3) and 12 months (T4)). Outcome measures of motor severity (Hoehn and Yahr score), gait (freezing of gait questionnaire) gait speed, step length and cadence), balance (timed single and tandem stance) and function (Falls Efficacy Scale, Nottingham Extended Activities of Daily Living) were made. Assessments were carried out in the home with individuals on medication. Regressions of measures of each outcome against time (P3-T4) provided variance ratios and associated p values for the null hypothesis. A P value of 0.05 was considered significant.

RESULTS: Significant improvements in motor symptoms following DBS-STN were found which were immediate and sustained showing reduced motor severity (Hoehn & Yahr scores) (P=.005), incidence and severity of freezing (Freezing of Gait Questionnaire) (P=.0004), and improved activities of daily living (Nottingham Extended Activities of Daily Living) (P=.01). However, there was no significant improvement in walking speed, step length, cadence, timed balance tests or reduced fear of falling.

CONCLUSIONS: Improvements in the distressing motor symptoms of PD do not translate to improved gait and balance outcomes underscoring the dopa-resistant nature of these clinical characteristics. These results highlight the need for specific rehabilitation aimed at gait and mobility in order to optimise the benefits of surgery and underscore the importance of a multidisciplinary approach to patient management.

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The effects of stroke involving the basal ganglia on control of axial segment reorientation during turning

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INTRODUCTION: Individuals with Parkinson’s disease (PD) show altered coordination during turning characterized by simultaneous rotation of the head and trunk and delayed onset of reorientation in all axial segments [1,2]. This indicates that the BG may play an important role in the control of axial segment reorientation during turning. We sought to explore the contributions of the BG to the control of turning by examining biomechanical deficits in turning in patients with stroke lesion involving the BG.

METHODS: Six participants (> 6months post-stroke) with MRI-confirmed lesions involving the BG (SBG), with lesions not involving the BG (SNoBG) and age-match controls (CBG, CNoBG) were asked to change walking direction by 45°, either left or right,

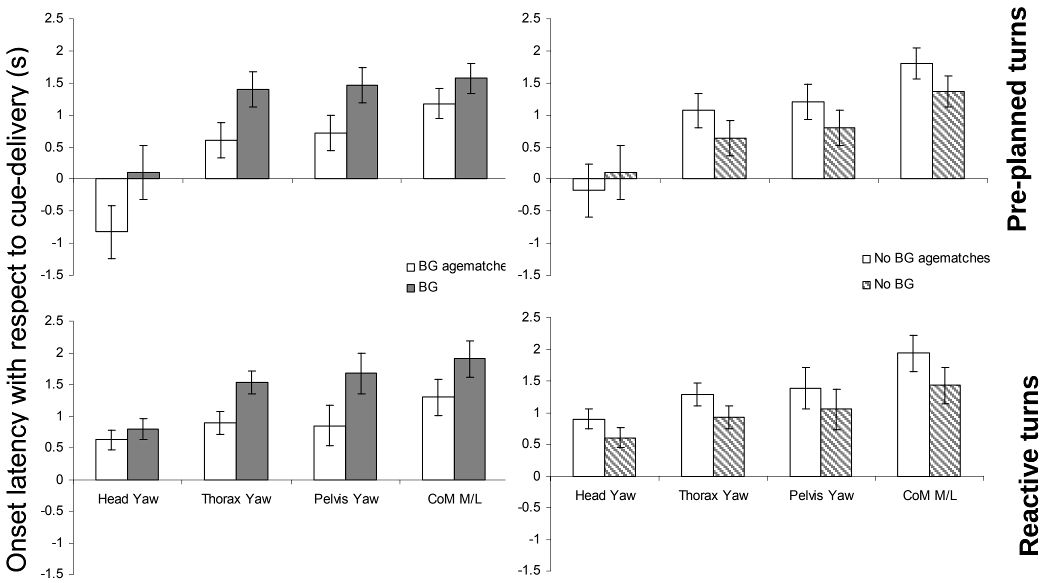

Fig 1. Mean axial segment reorientation onset latencies according to lesion sub-group

at the midpoint of a 6m path. Visually cues were given either at the start of the walk (pre-planned) or one stride before the turn point (reactive). Full body kinematics was measured using a Vicon MX motion analysis system.

RESULTS: Fig. 1 illustrates mean onset latencies with respect to cue delivery for each segment and for lesion subgroups. SBG participants initiated reorientation of each segment later than both CBG and SNoBG participants. SBG patients tended to initiate head reorientation much later in the pre-planned condition than the reactive condition and compared to other subgroups. Significant differences according to direction (P<.05), cue-condition (P<.05) and segment (P<.0001) as well as an interaction between cue-condition and segment (P<.001) were found (mixed design ANOVA).

CONCLUSIONS: The trend for SBG participants to have delayed onset of axial segment reorientation in the pre-planned condition and the fact that this delay was diminished when an external stimulus cued the initiation of the turn (reactive turn) indicates SBG patients may have similar impairments in internal cueing of movement sequences to those seen in PD patients. The difference between pre-planned and reactive turns in timing of axial segment reorientation of participants with BG stroke also highlights the potential for visual cues to improve turning ability following stroke affecting the BG.

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Parkinson's disease patients with freezing of gait: evidence for a specific impairment at the beginning of the single-support phase of the gait cycle

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INTRODUCTION: Freezing of gait (FOG) is a poorly-understood phenomenon occurring in advanced Parkinson's disease that is characterized by a sudden and involuntary inability to move forward. EMG studies [1,2] found abnormalities in intensity and timing of activation of lower leg muscles that are specific to PD patients with FOG (PD+FOG), compared to PD patients without FOG (PD-FOG), even during normal walking. In the present study, we used force-sensitive insoles that localize the center of pressure (COP) under each foot to test for abnormalities in COP dynamics in PD patients with and without FOG during normal walking.

METHODS: PD patients (N=29, 9 females, age 66±7 years, range 51-80 years) with motor fluctuations were tested during the "on" state of medication. Subjects had a mean UPDRS motor score of 20±7, with a mean duration of 9.4±4.7 years since disease diagnosis, and 3.3±2.8 years since motor fluctuations appeared. They completed three 2-minute walks back and forth along a 20m corridor at their comfortable walking pace, with a 180˚ turn at the each end of the corridor. Two of the walks also involved an additional cognitive task (serial subtraction of 3 or 7). Subjects wore capacitive force sensitive insoles (Pedar-X, Novel, Germany) that measure the center of pressure (COP) under each foot in the medio-lateral (ML) and anterior-posterior (AP) axes of the foot, at a frequency of 100 Hz. To assess presence and severity of FOG, patients completed a six-question FOG questionnaire [3], with higher scores indicating more severe FOG. Mean questionnaire scores were 9.9 ± 5.3 (range 1-21).

RESULTS: COP trajectories under the feet of PD patients contained abnormal patterns in both the AP and ML axes, consisting of backwards and lateral COP displacements that do not occur in healthy elderly during the corresponding phases of the gait cycle [4]. Furthermore, when correlating the reported FOG severity with occurrence of posterior and/or lateral COP displacements during different phases of stance, a significant correlation was found only during the beginning of single support and not during any other part of stance. Thus, the Spearman correlation between FOG questionnaire score and the occurrence of backwards or lateral COP movements at times between 20%-25% into stance, when single support starts, yielded significant correlations in all three walks (rho=0.50, 0.53, 0.60 for the three walks for backwards COP displacements at this time window, with $p<0.01$ for all three correlations, and rho=0.55, 0.65 and 0.68 with $p<0.003$ for lateral COP displacements within the same time bin). During other phases of stance there were only weak, usually insignificant correlations with FOG severity. Replacing the FOG questionnaire score with a sub-score that sums only the three questions related to the duration of FOG episodes of different types gave essentially the same results, as did a replacement of the correlations with t-tests for significant differences between the two groups that had above- and below-median scores in the questionnaire. Dual tasking exacerbated these observed abnormalities.

CONCLUSIONS: COP trajectories of PD patients during walking are abnormal. Our findings suggest that FOG severity in these patients is associated with a specific abnormality at the beginning of the single-support phase. This phenomenon may reflect the disease process, or may be a compensatory strategy that serves an adaptive purpose during normal walking. Possible relationships between the abnormal pattern of COP shifts and the mechanisms behind FOG episodes remain to be further studied.

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The influence of a secondary motor task and enhanced sensory feedback on turns in Parkinson's disease

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INTRODUCTION: Postural and gait instability may be one of the most debilitating problems associated with PD, since falling can limit independence. Dual task paradigms have become a useful method of identifying velocity and stride length impairments associated with [1]. Recent research has demonstrated the effectiveness of cutaneous sensory stimulation, to improve step initiation and velocity [2]. Thus, the purpose of the current study was to evaluate the influence a facilitatory insole which provides increased plantar stimulation, while performing the secondary motor task of carrying a tray during a turn.

METHODS: 7 PD participants completed a modified Timed-Up and Go (TUG) task which required them to rise from a chair, walk to a marked spot three metres away, turn around and walk back. Individuals completed this task under three conditions: 1) no tray; 2) empty tray; 3) tray with glasses. The task was completed with and without the facilitatory insoles. Each of these conditions was randomized and a total of thirty trials were completed. Data was collected on a data-collecting, pressure-sensitive carpet (GAITRite7, CIR Systems, Inc., Clifton, NJ, USA) and analyzed for number of steps to complete a turn, total time to complete the turn and various spatiotemporal aspects of gait.

RESULTS: Participants required more steps to turn when carrying a tray with glasses ($p<.0004$) compared to both empty tray and no tray conditions. Similarly, participants required more time to turn while carrying the tray with glasses ($p<.0287$). More interestingly, a significant interaction identified that participants spent more time turning while carrying a tray with glasses, when the facilitatory insoles were used (in contrast to without insole condition) ($p<.0499$) (Figure 1).

CONCLUSIONS: When carrying a tray with glasses, individuals with PD appear to require more steps and time to complete a turn. Thus, the secondary motor task of carrying a tray with glasses on it interferes with the primary motor task of turning. This supports previous work that identified difficulty performing a secondary motor task during straight line walking [1]. Interestingly, participants required more time to turn with the facilitatory insole, while carrying a tray with glasses than when they were not using the facilitatory insoles. These results will be discussed (with evidence from specific spatiotemporal aspects of gait) in terms of whether individuals with PD were trying to increase the sampling of sensory feedback provided by the facilitatory insoles, or whether the insoles acted as an additional distractor task.

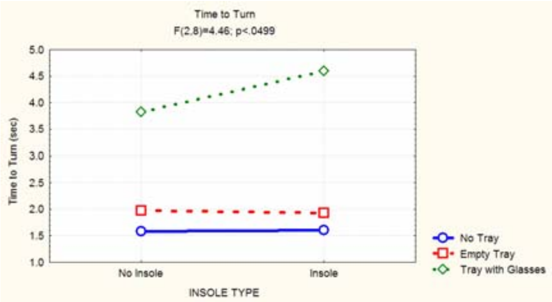

Fig. 1. Results of time to turn

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Freezing of gait in Parkinson's disease: Perceptual influences of doorway size on freezers and non-freezers

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Introduction: Freezing of gait (FOG) has been long thought of as a motor impairment. However, anecdotal patient reports have implied that these difficulties occur more frequently in confined spaces, and hence it is important to determine how perception of space might contribute to FOG. In an attempt to determine whether FOG may be related to a perceptual impairment, the present study evaluated how doorway size influenced characteristics of gait that might be indicative of freezing.

Methods: Changes in spatiotemporal aspects of gait were evaluated while walking through different sized doorways (narrow, normal, and wide) in three separate groups: 15 individuals with PD confirmed to be experiencing FOG at the time of test; 16 non-FOG individuals with PD; and 16 healthy age-matched control participants.

Results: Results for step length indicated that the FOG group was most affected by the narrow doorway and was the only group whose step length was dependent on upcoming doorway size [$F(2,44) = 13.11$, $p < 0.001$, see Figure 1]. Importantly, the FOG group also displayed increased within-trial variability of step length and step time, which was exaggerated as doorway size decreased condition [$F(4,88) = 2.99$, $p < 0.023$]. Base of support measures indicated that the non-FOG participants walked similar to the healthy group in the normal and wide doorway conditions, but acted similar to the FOG group in the narrow doorway condition.

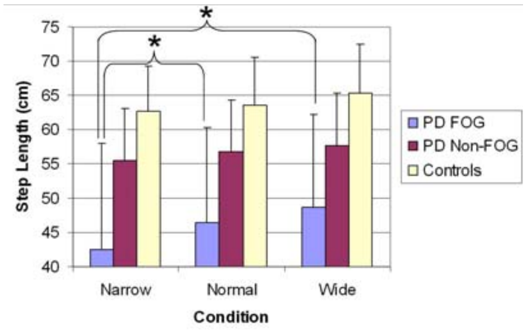

Fig.1 Changes in step length over the three conditions in the PD FOG group, PD Non-FOG group, and Controls

Conclusions: These results support the notion that some occurrences of freezing may be the result of an underlying perceptual mechanism that interferes with online movement planning. Neither healthy individuals nor individuals with PD absent of FOG exhibited this same effect.

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Differential effect of levodopa and subthalamic deep brain stimulation during dual task paradigm in Parkinson's Disease

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Introduction: Patients with Parkinson's disease (PD) have difficulties in performing two tasks simultaneously because of limited attentional ressources, defective central executive function and less automaticity in performing the tasks. Moreover, some studies suggest that subthalamic deep brain stimulation (STN-DBS) has an adverse effect on executive functions in PD patients. The aim of this study was to compare the effects of STN-DBS and levodopa on gait parameters during a double task (DT) in PD patients. Even if STN-DBS improves gait velocity and step length, may it increase the risk of falls because of adverse effect on attention process.

Methods: 11 PD patients treated by STN-DBS participated in this experiment. Spatiotemporal locomotor parameters were recorded using an automatic motion analyser (ELITE) under 4 treatment conditions (with and without STN-DBS and levodopa) and 2 experimental conditions: comfortable speed (CS) and during a DT of mental calculation while walking. We worked out a differential score between CS and DT for gait velocity, step length and cadence: ((mean gait parameter in NS – gait parameter in DT)/ mean gait parameter in NS)*100.

RESULTS: In both experimental conditions, step velocity and step length were significantly increased by levodopa and STN-DBS. The differential score assessing the effect of the cognitive task on gait parameters was significantly reduced for step velocity and step length under levodopa and STN-DBS as compared with the condition without any treatment. Concerning this index, the statistical analysis revealed no significant difference between levodopa and STN-DBS. Concerning the cadence, the differential score was significantly reduced for cadence under STN-DBS as compared with Levodopa condition.

CONCLUSIONS: Our data confirm that a cognitive DT worsens gait performances in PD patients and show that counting while walking has less pejorative influence on velocity and step length under STN-DBS and levodopa than without any treatment. However, the differential score of cadence was only reduced under STN-DBS. These results and previous studies which showed that PD patients increased cadence to compensate the primary reduced step length, suggest that STN-DBS may reduce the ability of PD patients to modulate gait in some circumstances. This reduction of PD patients' ability to modulate gait cadence under STN-DBS in response to the reduced step length may increase the risk of freezing episodes and the risk of falls particularly when performing two tasks simultaneously.

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Segmentation of activities discloses differential links between executive and locomotor function in Parkinson's Disease patients during Timed Up and Go with a dual-task

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INTRODUCTION: Previous studies demonstrated that a concomitant cognitive task significantly worsen gait and postural stability measures in subjects with Parkinson's disease (PD). Timed get up & go (TUG) is a well known test which involves several transitions of posture and gait that not only reflect functional tasks, but also a sequence of subtasks that are particularly sensitive to PD: sit-to-stand, gait initiation, straight walking, turning, and stand-to-sit. The purpose of this study is to explore in detail the relationship between objective measures of the different locomotor subtasks of TUG and clinical measures of executive functions, EF [1]. This research is a part of a prospective, multi-factorial study evaluating clinical, neuropsychological, biomechanical, patho-physiological, as well as neuroanatomical dimensions of PD in order to optimize treatment and physical/cognitive prescriptions.

METHODS: We examined 19 mild PD subjects (Hoen&Yahr ≤ 3, non-fallers, 45-72 years old, 9 women) in OFF state. To instrument the TUG we used a small tri-axial accelerometer (Dynaport Micromod, McRoberts), worn on the trunk at the level of L5. We also used a remote control to set temporal markers in order to segment the records in the go/turn/return phases of walking. The patients were instructed to get up from a chair without armrests, walk at their usual pace on level ground, covering a distance of 7 m, turn around a road cone, walk back, and sit down. The sessions included 3 reference single-task trials (ST) and 3 dual-task trials (DT) with a cognitive subtraction task (from 100 by 3's). We computed several temporal, coordination, and smoothness parameters such as gait speed, step duration (Tstep), Phase Coordination Index (PCI [2]) and Normalized Jerk Score (NJS [3]). The ΔTMT score of the Trail Making Test (Part B-Part A) was used to assess EF and was administered by qualified medical personnel during the same evaluation day. In order to evaluate the association of EF and performance of DT-TUG we performed a correlation analysis between ΔTMT and the difference in locomotor parameters between DT and ST trials.

RESULTS: All subjects showed a fair-to-good EF (ΔTMT=63±55s) and locomotor function (gait speed=1.2±0.2m/s). Interestingly, when analyzing the association between EF and DT-TUG considered as a whole we only found a mild correlation with NJS ($r=0.57$, $p=0.02$). Instead, when the subtasks of TUG were analyzed separately, we found a variety of stronger correlations: with symmetry and coordination parameters in the go-phase ($r>0.7$, $p<0.005$) and with smoothness parameters during turning ($r=0.7$, $p<0.05$). No significant correlations were found during the return-phase and transitions.

CONCLUSIONS: All significant correlations found after segmentation of TUG were positive to indicate that a decrease in EF reflects in a decrease of smoothness, coordination and symmetry of movements as a consequence of a DT. Such changes are specific of different subtasks of the DT-TUG suggesting differential, dynamic attentional demands involved in TUG sequential locomotor tasks. In particular, during turning we disclosed a strong association between smoothness of movement (NJS) and cognitive flexibility. Also, based on these results, the cost of the go and return walking phases of DT-TUG may be differently sensitive to the level of EF.

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Interlimb strategies for obstacle clearance following stroke

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Introduction: Following a stroke, the ability to safely step over obstacles decreases and the risk of falling increases [1]. Previous studies investigating obstacle clearance following stroke have focused on movement kinematics [1,2] except one study that examined centre of pressure [3]. These studies have shown that participants with a previous stroke step closer to the obstacle with the hemiparetic limb prior to clearing it and show less clearance with the hemiparetic trail limb [2]. Although healthy adults have been shown to use a knee strategy for obstacle clearance [4], little is known about the strategies used following stroke. The aim of this study is to determine limb elevation strategies to step over obstacles in persons with a previous stroke. Preliminary results are presented.

Methods: Four participants with a previous stroke (range 3 – 54 months post stroke) have been recruited to date. Participants started approximately 3 steps away from an obstacle (heights of 5 and 15% of their leg length) and cleared it leading with their hemiplegic and non-hemiplegic sides. Kinematic (joint, foot and body motion) data were collected with a 3-bar Optotrak system (60 Hz) and a linked segment model of the body was created containing head, trunk, pelvis, thighs, legs, and feet. Ground reaction forces from the lead and trail limbs were collected using 3 AMTI force plates (1000 Hz). Kinetics (muscle moments and powers) were estimated using an inverse dynamics approach and muscle mechanical work was estimated by integration of the muscle power curve. A three-way ANOVA was used to determine within subject differences between sides (hemiparetic, less affected), crossing limbs (leading, trailing), and obstacle heights (5%, 15%).

Results: Maximum toe height over the obstacle was higher for the lead limb when compared to the trail limb ($p < 0.011$). No differences were observed between hemiparetic and less affected sides for maximum toe height pre-obstacle foot position, center of mass velocity during crossing strides, and post-obstacle foot position. Significantly more positive mechanical work was produced by the knee flexors during limb elevation on the less affected side when compared to the hemiparetic side in the leading and trailing limbs ($p < 0.007$). This difference in knee work was accompanied with a significant increase in hip joint elevation between toe off and maximum height, that was greater on the hemiparetic side, particularly for the trailing limb.

Conclusions: These preliminary results suggest that persons with stroke use a knee strategy similar to healthy adults to successfully clear an obstacle although the strategy is augmented with hip hiking. This may be due to a decrease in knee flexor muscle strength or interjoint coordination on the hemiparetic side. More subjects and further analyses are continuing in order to provide guidance for rehabilitation programs.

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Curved walking in individuals with stroke

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Introduction: Despite the significance of turning during walking in everyday life there has been very little research on turning capacity in ambulatory individuals suffering from stroke-related hemiparesis. In able-bodied gait, temporal features required for straight walking become increasingly asymmetric when travelling along a path of increasing curvature. For example, the inner leg of the turn remains in single support longer while the outer leg swings around to direct the body along the curved path. During straight walking post-stroke, stance duration on the non-paretic side tends to be longer compared to the paretic side. The tendency to favor weight bearing on the non-paretic limb might restrict the extent to which interlimb asymmetry can be adapted to increasing path curvature during turns to the paretic side (ie: when the paretic leg is the inner leg of the turn). Hence, turns to the non-paretic side may be favored. The purpose of this study was to examine the pattern of asymmetry in stroke survivors when walking along a curved path. It was hypothesized that stroke participants would show more difficulty turning to their paretic side than turning to their non-paretic side.

METHODS: Participants with a history of stroke resulting in hemiparesis and age-matched controls were recruited for this study. Physical impairment due to stroke was assessed using the Chedoke-McMaster scale for the leg and foot. The participants were asked to walk at their self-selected walking speed along four paths of different curvatures: straight path, large circle (radius = 2 m), medium circle (radius = 1 m) and small circle (radius =0.5 m). High-speed motion capture cameras were used to monitor body motion and force sensitive resistors were used to estimate the center of pressure under both feet. Difficulty turning was defined by time to walk the path and changes in gait asymmetry during curved walking compared to the control group.

RESULTS: Pilot testing has been completed in 14 individuals (4 strokes, 10 controls) and revealed that control participants spent more time on the inner leg of the turn compared to the outer leg. This became increasingly evident with increasing path curvature. Stroke participants spent more time on their non-paretic leg relative to their paretic leg during both the straight walking and the curved walking trials. Turns to the paretic side did not change the degree of asymmetry relative to the straight walking trials but participants did increase the time spent on the non-paretic limb when turning to the non-paretic side. There appears to be a relationship between the degree of physical impairment and the ability to adopt and asymmetric walking pattern in response to path curvature.

CONCLUSION: Turning difficulties in people with stroke could be associated with reduced capacity to spend time on their paretic leg when turning to the paretic side. Although stroke survivors managed the curved path, they were not able to adopt the asymmetric pattern typically seen in able-bodied individuals. There has been little attention to-date on this important task required for functional mobility. The results from this study could have implications for the assessment and rehabilitation of gait post-stroke. Data collection is ongoing and full results will be presented at the meeting.

P.300

Stepping adjustments under time-critical situations are impaired, even in mildly affected stroke patients

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INTRODUCTION: Stroke survivors are at risk of falls, which may be due to difficulties they experience in the on-line gait adjustment in response to environmental constraints. For example, walking over uneven terrain and the avoidance of a sudden obstacle require such on-line adaptations of gait. Even mildly affected stroke patients may be less successful in avoiding obstacles while walking, particularly under time pressure. To gain insight into the mechanisms underlying stroke-related deficits in time-critical stepping adjustments, the present study evaluated leg muscle EMG characteristics during obstacle avoidance.

METHODS: Eight chronic (> 1.5 years) stroke patients (aged 54 ± 10 years) and 10 healthy controls (aged 63 ± 10 years) were included. All patients were community ambulators with a Functional Ambulation Categories score 5 (ability to walk over uneven terrain) and used no walking aids. Lower extremity Fugl Meyer scores were on average 65% and Berg Balance Scale scores 52/56. The patients walked with a regular polypropylene ankle-foot orthosis on a treadmill at either 2 or 3 km/h, depending on walking ability, whereas the healthy controls performed the protocol at both 2 and 3 km/h. A total of 30 obstacles was dropped on the treadmill in different phases of the step cycle, in front of the affected leg of the patients and the left leg of the healthy subjects. The participants had to make fast stepping adjustments to avoid the obstacle. Avoidance success rates were determined, as well as EMG-response onset latencies and amplitudes from bilateral biceps femoris (BF), rectus femoris (RF), tibialis anterior (TA) and gastrocnemius medialis (GM) muscles.

RESULTS: Success rates were much lower in patients compared to controls (2 km/h: 29.2 ± 3.4% versus 94.6 ± 1.9%; 3 km/h: 48.1 ± 3.6% versus 89.1 ±1.2%). Success rates progressively decreased with increasing time pressure, particularly in the stroke patients. In the patient group, all ipsilateral and contralateral muscle onset latencies were delayed compared to the controls. (Mean differences for BF 44 and 45 ms, RF 38 and 33 ms, TA 15 and 38 ms, GM 49 and 33 ms for ipsi- and contralateral side respectively). Overall, EMG amplitudes were smaller in the patients, which was most pronounced in the ipsilateral BF (27% of healthy controls).

CONCLUSIONS: The results show that the ability to make time-critical stepping adjustments was compromised in the patients. The delayed and reduced muscle responses may explain their deteriorated obstacle avoidance ability. The delayed onset latencies also indicate that gait automaticity is not easily restored even in mild stroke patients and that these patients probably depend more heavily on cognitive gait control than healthy individuals. Finally, the findings suggest that the assessment of stepping adjustments may be a sensitive measure in the evaluation of gait skills and fall risk in relatively mildly affected patients.

P.301

Comparisons between stroke and healthy subjects with different performances in the Timed "Up and Go" test: A functional approach

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INTRODUCTION: Hemiplegics show poorer performance in the Timed "Up and Go" test (TUG) than healthy subjects [1]. However, these comparisons were never conducted in groups with different functional levels. In health conditions related to acquired brain injuries, such as stroke, a number of interrelated variables may contribute to specific levels of functioning. Therefore, it is important to know the different levels of functioning and the kinds of functional variables that could predict those levels. Therefore, the aim of this study was to compare hemiplegics and healthy subjects with different levels of functioning, as determined by slow, intermediate, and fast performance of the TUG. In addition, it aimed to point out the functional variables, selected according to the International Classification of Functioning, Disability and Healthy (ICF) [2] which could be combined to predict performance levels.

METHODS: Twenty-two community hemiplegics (54.73±15.42 years) and 22 healthy subjects (54.73±15.38 years) were matched by gender, age, and levels of physical activity. They performed the TUG and were assessed for quadriceps strength (ICF category of body structure and function); maximal gait speed (ICF category of activity); and their quality of life (ICF category of participation). Each group was divided into three sub-groups: fast (seven subjects), intermediate (seven subjects), and slow TUG (eight subjects). Mixed repeated measure ANOVAs were employed to investigate the main and interaction effects between groups and subgroups. Discriminant function analyses were applied to predict group membership (α=0.05).

RESULTS: For both groups, the three subgroups were significantly different regarding the TUG performance: Hemiplegics subjects: Fast=12.76±2.93s; intermediate= 20.99±3.22; and the slow subgroup=28.4±20.09s (F=26.21; p<0.013); Healthy subjects: Fast=7.26±0.54s; intermediate=9.02±0.78s; and slow sub-group: 11.35±1.36s (F=32.73; p<0.006). Significant interactions were found between the groups and sub-groups (F=21.35; p<0.001): Faster hemiplegics showed similar performances to all of the healthy sub-groups. Maximal gait speed and quality of life showed two statistically significant discriminant functions (p=0.008) and correctly classified 86.4% of the original grouped cases (Table 1).

CONCLUSIONS: Hemiplegics with the fastest TUG speeds showed similar performance to the healthy subjects. Group membership was correctly classified for the majority of the subjects only for the functional variables related to activity levels and participation.

ACKNOWLEDGEMENTS: ISB (Student Dissertation Award), CAPES, FAPEMIG, Graduate Student's Exchange Program (Government of Canada).

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	Predicted Group Membership				
Actual Group	**Healthy**	**Stroke-Fast**	**Stroke-Moderate**	**Stroke-Slow**	TOTAL
Healthy	**21 (95.5%)**	0	1 (4.5%)	0	22
Stroke-Fast	2 (28.6%)	**3 (42.9%)**	2 (28.6%)	0	7
Stroke-Moderate	0	1 (12.5%)	**7 (87.5%)**	0	7
Stroke-Slow	0	0	0	**7 (100%)**	7
Total of correctly classified original group: 38 (86.4%)					

Table 1: Discriminant Analyses for Classifying Levels of Functional Performance

P.302

Stroke patients with lateropulsion (pusher syndrome) have a lower functional independence at discharge from the rehabilitation hospital

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INTRODUCTION: There is a controversy in the literature about the rehabilitation prognosis of stroke patients with the pusher syndrome (lateropulsion). The aim of the study was to investigate the difference in functional independence of pushing and non-pushing stroke patients at the start and at discharge of rehabilitation.

METHODS: We retrospectively analyzed the FIM-scores and length of stay of 19 pushing and 118 non-pushing stroke patients who entered the Rehabilitation Hospital Hof ter Schelde in Antwerp (Belgium) and participated in a conventional interdisciplinary rehabilitation. The outcome measures were: Functional Independence Measure at 3 weeks after admission and at discharge from the rehabilitation hospital; length of stay in rehabilitation; effectiveness, efficiency and efficacy of the rehabilitation.

RESULTS: Left hemiplegic stroke patients with pushing syndrome had significantly (p<0.01) lower scores on the total FIM, the motor and cognitive FIM-subscales, both 3 weeks after admission (W3: 61.4, 39.8, 21.6 respectively) and at discharge from rehabilitation (72.1, 48.5, 23.6 respectively), compared to non-pushing left hemiplegic patients (W3: 81.6, 55.9, 26.3 and at discharge: 94.3, 67.1, 27.2 respectively).

	Pushing (L-hemipl)	Non-pushing (L-hemipl)	p
Lengthof stay (days)	92.5	67.15	.04*
Effectiveness	19.70	12.70	.99
Efficiency	0.27	0.20	.96
Absolute efficacy	0.22	0.32	.34
Relative efficacy	0.01	0.34	.39

Table 1: Mean effectiveness, efficiency and efficacy of the rehabilitation for pushing and non-pushing subjects with left-sided hemiplegia

Pushing patients stayed 25 days (37.7 %) longer in the rehabilitation hospital compared to non-pushing patients. There was no difference between both groups for effectiveness, efficiency or efficacy.

CONCLUSIONS: Left hemiplegic stroke patients with pushing syndrome have a lower functional independence at the start of the rehabilitation compared to non-pushing left hemiplegic patients. They improve during the rehabilitation process with comparable effectiveness, efficiency and efficacy as non-pushing patients, but remain less functionally independent at discharge.

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Asymmetry of centre of pressure during quiet stance predicts gait performance in chronic hemiparetic patients

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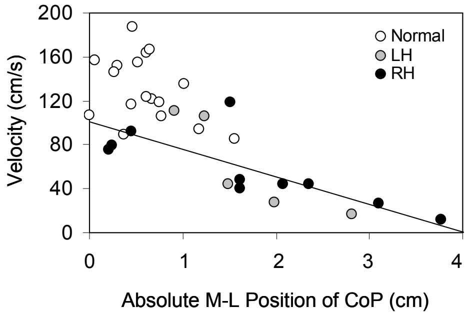
INTRODUCTION: In patients with spastic hemiparesis, centre of foot pressure (CoP) is usually shifted toward the unaffected limb during quiet upright stance [1]. In this study, we hypothesised that abnormal gait features are correlated with the degree of asymmetry during stance [2].

METHODS: Fifteen patients and 17 normal subjects were recruited. Position and sway of CoP were recorded with eyes open (EO) and closed (EC) on a force platform. Spatial-temporal variables of gait were measured with pedobarography.

RESULTS: The mean medio-lateral (M-L) position of CoP in patients was shifted toward the unaffected limb, while its antero-posterior position was similar to normals. Sway area and sway path were larger in patients than normals, both with EO and EC. These abnormalities were not influenced by the side of lesion. However, CoP M-L position was associated with decreased strength of the affected lower limb muscles. No relationship was found between sway and CoP M-L position. The spatial-temporal variables of gait were affected by the disease, irrespective of the side of lesion: cadence and velocity were decreased in patients, while duration of single support on the unaffected limb and of double support were increased with respect to normals. In patients, there was a negative relationship between velocity and CoP position (Fig. 1, left), as well as between cadence and CoP position. Duration of the single support on the unaffected side was positively correlated with CoP position (Fig. 1, right). Duration of double support of the patients correlated positively with CoP M-L position.



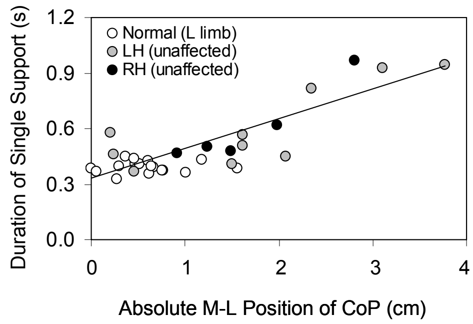


Fig.1 Upper panel: relationship between velocity of gait and M-L position of CoP during stance in normal subjects, left hemiparetic (LH) and right hemiparetic (RH) patients. Lower panel: relationship between duration of single support (unaffected limb for the patients) and M-L position of CoP in the same subjects and patients.

CONCLUSIONS: The lack of a relationship between body sway and gait variables suggests that postural instability itself is not a limiting factor in gait in hemiparetic patients. Conversely, gait performance is biased by the asymmetry of CoP M-L position, regardless of the side of the lesion. It is suggested that the difficulty to move the body toward the affected limb [3] plays a role in gait slowing. The asymmetry during both standing and walking suggests that in hemiparetic patients posture and gait are locked together, and that postural and gait problems share some common neural origin [4]. Stabilometry can be used both to measure the degree of postural asymmetry and to predict impairment of gait variables.

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P.304

Increasing intensity of treadmill walking: the effect on walking quality early following stroke

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INTRODUCTION: Following stroke, most survivors are able to walk[1] but few manage this easily in the community[2], significantly contributing to the ongoing disability associated with stroke. While treadmill training is increasing in popularity as a mode of retraining walking, the impact of this on walking quality has not been investigated. The purpose of this study was to determine whether walking on a treadmill at increasing intensities adversely affected walking quality during walking practice or afterwards in overground walking in newly-ambulatory stroke patients.

METHODS: A within-participant, repeated measures experimental study was undertaken with 18 first stroke patients undergoing inpatient rehabilitation. Participants walked on a treadmill at intensities equivalent to 30, 40, 50 and 60% heart rate reserve, the minimum intensity for improving cardiorespiratory fitness. Walking was measured as linear and angular kinematics using GAITrite and a 2D posterior and lateral webcam application. Walking quality was measured using the Rivermead Visual Gait Assessment scale and a visual analogue scale.

RESULTS: Walking on the treadmill at 60% HRR, step length of the paretic limb was 0.05 m (95% CI 0.01 to 0.10) longer, step length of the non-paretic limb was 0.09 m (95% CI 0.05 to 0.12) longer, and hip flexion at mid swing was 4 deg (95% CI 1 to 6) greater than at 30% HRR. At 60% HRR, hip and knee extension at mid stance were respectively 3 and 4 deg more flexed than at 30% HRR. Walking ability did not affect these changes in walking pattern. Walking quality did not change with increasing treadmill intensity.

CONCLUSIONS: Walking on a treadmill at increasing heart rate intensity did not adversely affect walking pattern or reduce walking quality in this group of newly-ambulating stroke patients. This study provides support to the evidence base for the use of treadmill walking at higher intensities in rehabilitation programs for newly-ambulating stroke patients.

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On the relative contribution of the paretic leg to control of posture after stroke

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INTRODUCTION: The postural control system is very flexible and may employ various compensatory strategies. Asymmetric weight bearing often accompanies stroke [1]. However, the origin of weight-bearing asymmetry remains largely unknown. Is it caused because the paretic leg is too weak to bear a lot of weight or may it be viewed as an effective compensatory strategy? The objective of the present study was to examine the relative contribution of each leg to postural control in patients recovering from stroke while taking the clinically scored sensory and motor impairment of the paretic leg into account. A greater contribution of the nonparetic leg was expected, particularly in patients with ankle clonus, disturbed sensibility, and lack of selective muscle control on the paretic side.

METHODS: A cohort of 33 stroke patients was evaluated at 5 stages during 3 months of inpatient rehabilitation [2]. Participants were instructed to stand as symmetrically as possible under both sensory and cognitive manipulations, while a dual-plate force platform was used to assess the contribution of each leg to postural control, quantified by the amplitude, velocity, and regularity [3] of center-of-pressure trajectories.

RESULTS: With follow-up assessments, weight-bearing asymmetry and postural steadiness improved. Patients strongly relied on visual information. When attention was distracted by having the patients perform an arithmetic task, weight-bearing asymmetry increased, suggesting that symmetric weight bearing was attention demanding. Patients with severe motor impairments of the paretic leg showed greater static (weight-bearing) and dynamic (lateralized control) asymmetries than patients with limited motor impairments, whereas postural steadiness did not differ between these subgroups. Disturbed sensation did not affect weight-bearing asymmetry, postural steadiness, or lateralized control.

CONCLUSIONS: Patients with severe motor impairments of the paretic leg employ an effective compensatory strategy that includes asymmetric weight bearing and lateralized control [4]. Although often regarded as a primary goal in rehabilitation, our study suggests that training to improve weight-bearing symmetry may not be advisable if patients exhibit rather severe motor impairments of the paretic leg.

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P.306

Analysis and comparison of electromyographic activity of gait muscles in normal young individuals with and without the use of an ankle brace developed for patients with hemiparesis

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INTRODUCTION: Ankle-foot orthoses (AFO) are often prescribed to those patients to obtain a better heel-strike, and are used to improve gait pattern and or gait speed of hemiparetic patients [1-3]. Objective: The aim of the present study was to analyze and compare electromyography EMG) signals in the gait muscles of normal young individuals with and without the use of an ankle brace developed for patients with hemiparesis.

METHODS: Sixteen healthy normal young individuals (11 women, 6 men; mean age of 22 ± 3.63 years) participated in the study. All participants walked a catwalk (5 m long, 1.5 m wide) first without the brace and then with the brace. The EMG signals of the following muscles were determined simultaneously on the left leg of all individuals under both conditions: soleus, anterior tibial, vastus lateralis and rectus femoris. The experimental brace is comprised of a single cloth piece and steel spring that fits over the foot and 1/3 of the distal region of the tibia (Figure 1). EMG activity was captured by an EMG system (EMG System do Brasil), composed of 16 channels, with a frequency band filter between 20-500Hz, amplifier with 100X gain and self-adhesive, disposable passive surface electrodes with a coupled 20x pre-amplifier (Medtrace). Following verification with an Ibramed TENS, the electrodes were placed on the motor point of the muscles assessed. Analysis The data were expressed as mean ± standard deviation and analyzed using the Student's *t*-test.

RESULTS: The mean EMG signals of the muscles revealed no significant differences. The anterior tibial muscle exhibited the greatest increase in mean EMG activity with the brace (-4.54 ± 12.21) in comparison to without the brace (-4.22 ± 15.81), but the difference did not achieve statistical significance ($p > 0.05$).

CONCLUSION: When using the brace, the participants exhibited slight, non-significant increases in mean EMG activity in the rectus femoris, vastus lateralis and soleus when compared to non-use of the brace. The anterior tibial muscle exhibited the greatest increase in mean EMG activity (although also non-significant), which was expected due to the fact that one of the functions of the brace is to aid in the dorsiflexion of patients with hemiparesis stemming from stroke events.

Fig. 1 The experimental brace

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P.307

Posture effect on chest wall motion in patients with spinal cord injury.

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INTRODUCTION: Patients with spinal cord injury (SCI) have respiratory disability depending on their lesion level [1]. Previous study indicated that changing posture from sit to supine can increase lung volume in SCI [2], but there was lack of studies to investigate the posture effect of chest wall motion by three-compartment model, including upper thorax (UT), lower thorax (LT), and abdomen (AB) [3]. Therefore, the purpose of this study was to explore the posture effect on chest wall motion in tetraplegic and paraplegic patients.

METHODS: Five tetraplegic patients (with age 35.40±11.76 years, body height 169.80±1.92 cm, body weight 64.40±10.26 kg) and 7 paraplegic patients (with 38.71±12.68 years, body height 169.36±9.30 cm, body weight 68.57±8.50 kg) were recruited in this study. Optoelectronic plethysmography was used to measure the chest wall motion and estimated lung volume. There were 45 makers on the chest wall to identify three compartments (UT, LT, and AB) during breathing from functional residual capacity to maximal inspiration in sitting and supine posture. A two-way repeated measure ANOVA (2 groups X 2 postures) was performed. The alpha level was set at 0.05.

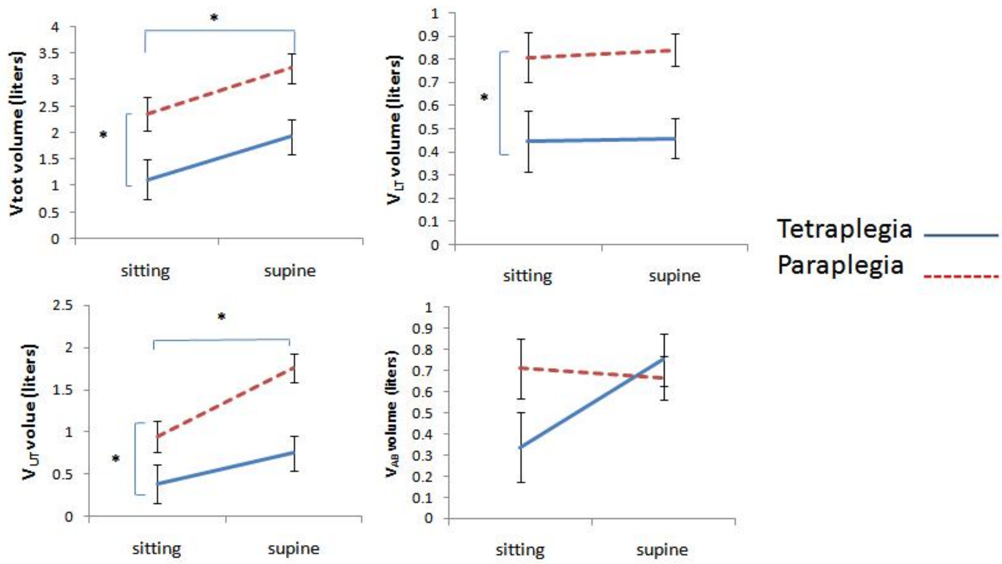

Fig.1 The volume changes of three compartments in patients at different postures

RESULTS: The total volume changes (V_{tot}) showed significant main effects of posture (p=0.015) and group (p=0.006), but there was no interaction between posture and group. The upper thoracic volume (V_{UT}) showed significant main effects of posture (p=0.02) and group (p=0.02), but there was also no interaction between posture and group. The lower thorax volume (V_{LT}) only showed a significant main effect of group (p=0.013). There was no significant finding in abdominal volume (V_{AB}). These results indicated that V_{tot}, V_{UT}, and V_{LT} of paraplegic group were significantly larger than tetraplegic group and V_{tot}, V_{UT} in supine position were significantly larger than in sitting position. V_{AB} did not change with different postures.

CONCLUSIONS: The lung volume changes estimated by chest wall motion in paraplegic group were significantly larger than those in tetraplegic group, Supine position benefited the chest wall motion in SCI, especially for upper thorax.

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P.308

An exploratory analysis of lateral reach: a comparison between healthy subjects and people in the first three months after stroke

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INTRODUCTION: Lateral reach, a task where a seated subject reaches as far to the side as possible is frequently used by physiotherapists to retrain balance. The normal movement literature suggests that a lateral reach is combined with a midline position of the head to keep the eyes horizontal. The aim of this study was to examine the latter hypothesis in healthy subjects and compare the lateral reach of healthy participants and people after stroke over time.

METHODS: We evaluated 13 healthy controls and eight people with acute stroke at baseline and three and nine weeks later. Subjects were asked to reach sideways as far as possible while retaining visual attention on a signal in front. Markers were attached (face, wrist, trunk, pelvis) and 3-D motion recordings were made using CODAmotion. Data analysis consisted of non-parametric descriptive statistics and non-parametric inferential statistics (Mann-Whitney U tests) to compare variables between people after stroke and healthy controls. Level of significance was set at p<0.05.

RESULTS: Healthy controls demonstrated similar displacements of trunk (mean 30+/-5.34 degrees) and pelvis (27.09+/-7.12 degrees) at baseline. Both displacements increased significantly after three and nine weeks [trunk (p=0.006) and pelvis (p=0.013)]. Mean head position at baseline was 9.8+/- 8.94 degrees tilted towards the side of lateral reach and increased significantly with repeated sessions (p=0.005) as well. Furthermore, the task was performed quicker at nine weeks than at baseline (p=0.003). People with stroke showed similar mean displacements of trunk (22.66 +/- 12.59 degrees) and pelvis (19.03+/-11.95 degrees) at baseline but these did not increase over time. As a result, the angular displacements were significantly lower in comparison to healthy subjects after three (p<0.000) and nine weeks (p<=0.001).

CONCLUSIONS: Our findings suggest that when performing a lateral reach healthy controls learn over time to reach further and perform the task quicker. Contrary to common belief, the head is not held in a midline position. Our sample of people after stroke showed a shorter lateral reach and did not demonstrate evidence of recovery.

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Marked impairments in the bilateral coordination of gait in post-stroke patients

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INTRODUCTION: One of the unique aspects of gait is the bilateral coordination required to control left and right foot timing. Mechanisms of the coordination of bipedal human walking are not fully understood. A new metric, the phase coordination index (PCI), was recently developed in order to quantify the bilateral coordination of stepping during functional forward walking. The metric focuses on the phase of the gait cycle of one leg with respect to the other. Using this methodology, it was recently found that patients with Parkinson's disease (PD) have impairments in left-right stepping coordination. The objective of the present work was to study if patients with another asymmetric cerebral disease, stroke, would have deficiencies in bilateral coordination of the gait that could be quantified using the PCI. Further, whereas the original development of the PCI was based on data from footswitches, here we adapted it to accelerometer-based measures.

METHODS: The gait of straight line walking (~120 m) of twelve healthy older adults (mean age: 55.1 ± 1.8 yrs) and twelve patients with hemiplegia (mean age: 54.2 ± 3.1) was studied. Bilateral coordination of gait was assessed by examining the phase between the step timing of the left and right legs, as determined using a 3-D accelerometer (McRoberts). Specifically we quantified the stride duration of one foot as a gait cycle or 360°, determined the relative timing of contra-lateral heel-strikes, and defined this as the phase, φ (ideally, φ=180° for every step). The sum of the coefficient of variation of φ (φ_CV) and the mean absolute difference between φ and 180° (φ_ABS) was defined as the PCI, representing variability and inaccuracy, respectively, in phase generation. We also quantified gait asymmetry (GA): GA=100*ILN(RSW/ LSW|, where RSW and LSW represent the mean values of the left and right swing time, respectively.

RESULTS: PCI and GA were larger in the stroke patients, as compared to aged-matched controls (Table 1). PCI was strongly correlated with GA in the stroke patients (R^2=0.83, p<0.001) as compared with the correlation seen in elderly subjects ((R^2=0.38, p=0.03). No significant correlations were seen in both groups between GA or PCI and gait speed.

CONCLUSIONS: As anticipated, the PCI is very different in post-stroke patients compared to age-matched controls. These findings further demonstrate that this index may be used as a sensitive measure of the bilateral coordination required to successfully ambulate. Perhaps it may also help to quantify stroke severity and the response to therapeutic interventions.

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Parameter	Stroke patients	Healthy Elderly	P-value
PCI (%)	19.5 ± 2.3	6.2 ± 1.0	<0.001*
GA (%)	26.3. ± 5.6	5.6 ± 1.2	0.001
Gait Speed (m/s)	1.1 ± 0.1	1.7 ± 0.1	0.001
*ttest			

Table 1. Gait and bilateral coordination parameters. Means ± SE

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Walking along circular trajectories in chronic hemiparetic patients

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INTRODUCTION: We hypothesised that gait capacities would be more stressed in hemiparetic patients when walking along curved than straight trajectories, owing to the complex adaptations required for this walking task that likely challenges their poor postural and walking abilities [1].

METHODS: Nineteen chronic hemiparetic patients and 20 normal subjects walked eyes-open along straight and curved trajectories for 1 min at self-paced cadence and velocity. Step frequency and total distance travelled along straight and curved trajectories (clockwise and counterclockwise, radius 1.5 m) were computed from video-recordings of the lower limbs. From these measures, mean step length and gait velocity were calculated. Pedobarography was performed to detect the degree of internal-external rotation of the feet during the stance phase of linear gait.

RESULTS: 1. Step frequency, step length and travelled distances were smaller in patients than normal subjects during straight trajectories. 2. Step frequency was decreased to the same degree by circular trajectories in both patients and normal subjects. Step length and distances were shorter during curved than straight walking in patients; in particular, the ratio between curved and linear velocity was significantly smaller in patients than normal subjects (about 80% and 70%, respectively). 3. Gait velocity, either curved or linear, was positively correlated with muscle strength of paretic limb. 4. Gait velocity during curved trajectories was independent of the affected body side or sense of rotation. 5. Gait velocity, either during linear or curved trajectories, was negatively affected by the external rotation of the paretic with respect to the non-paretic foot. 6. However, external rotation favoured speed when the paretic foot was inside rather than outside the curved trajectory (Fig. 1).

CONCLUSIONS: Walking along curved trajectories is more sensitive than walking along linear trajectories in highlighting impaired gait control in hemiparetic patients. Possibly, the orientation of foot towards the centre of the trajectory facilitates walking along the curved trajectory, as occurs in normal subjects, who place their inner foot rotated towards the centre of the trajectory [2]. Since the foot orientation affects velocity, we suggest performing appropriate rehabilitation exercises targeting foot rotation of the affected limb.

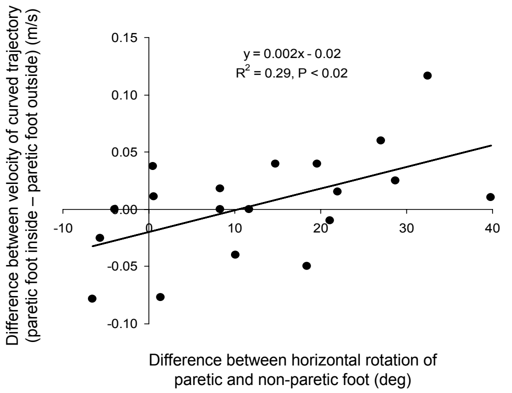

Fig.1 In the patients the gait velocity along the circular path (difference in velocity travelled with the paretic foot inside with respect to outside the trajectory) increases progressively as a function of the degree of the extrarotation of the paretic foot (expressed as the rotated angle with respect to the non-paretic foot) when the paretic foot is placed inside the trajectory.

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Short latency stretch reflexes do not play a major role in the premature calf muscle activity during the stance phase of gait in patients with UMN-syndrome

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INTRODUCTION: Upper motor neuron syndrome (UMNS) may lead to impaired control of the lower limb muscles, e.g. loss of muscle selectivity and spasticity, which often results in gait disorders with abnormal muscle activation patterns. These patterns often include premature activity of the calf muscles during the stance phase. On the other hand, the calf muscles are less active at the end of the stance phase, leading to a lack of push-off. The aim of this study was to investigate the relationship between the premature activity of the gastrocnemius (GM) during the first half of the stance phase, and the muscle lengthening velocity of the GM. We expected that lengthening of the GM during stance induces short latency stretch reflexes leading to premature activation of the GM in patients, while control subjects are able to inhibit these reflexes to stretch.

METHODS: Twelve subjects with UMNS (9 stroke patients (age 57±8), 6 patients with hereditary spastic paraparesis (HSP) (age 45±13)) and 13 control subjects (age 41±17) were included in the study. All participants walked barefooted on a walkway at comfortable speed. Lower body kinematics were recorded using Vicon Motion System and electromyographic (EMG) data were recorded from bilateral GM. Five gait cycles were used for further analysis. Musculo-tendon lengths were estimated based on the musculoskeletal model developed by Delp [1], and differentiation of length resulted in lengthening velocity. Based on the duration of the short latency stretch reflex (SLR), a delay of 40 to 80 ms was expected between the stretch reflex inducing event and the resulting muscle response (increased activity), so we assumed that the pattern of muscle activity and muscle lengthening velocity should be related to each other with a delay of 40 to 80 ms. For each stance phase, we did a cross-correlation analysis to identify at which time lag muscle lengthening velocity showed the highest level of agreement with the muscle activity pattern. The primary outcome measure was the mean time lag over the five gait cycles at which the highest cross-correlation value was observed in each subject. Positive time lags corresponded to a delay of muscle activity relative to muscle lengthening velocity.

RESULTS: Patients indeed showed premature activity of the calf muscles during the stance phase. The maximum lengthening velocity of the calf muscles was on average 7.71 cm/s in controls, 5.04 cm/s in HSP patients. In stroke patients the maximum velocity was 4.88 cm/s and 5.31cm/s in the affected and unaffected leg, respectively. In the HSP patients, the time lags ranged from 1 to 119 ms and only two of the mean time lags were within the SLR time window. The time lags for the affected leg of stroke patients were all outside the SLR time window (mean: -125 to 20 ms). Two time lags for the unaffected leg were within the SLR time window (mean: -107 to 68 ms). Finally, in controls, the time lags of 4 subjects were within the SLR time window and ranged from 7 to 70ms.

CONCLUSIONS: Although the patients did have gait impairments with premature calf muscle activity typical for UMN syndrome, no (clear) relationship was found between lengthening velocity and the activity of the GM. Premature activity of the GM may have other causes than the short latency stretch reflex, such as positive support reactions, or associated balance reactions. Given the low GM lengthening velocities in the patients it is also suggested that these velocities may be too low to elicit a short latency stretch reflex.

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Enhanced somatosensory input and gait stability

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INTRODUCTION: While postural control during quiet stance can be enhanced by haptic input [1], the role of tactile cues on gait ability in healthy or neurological populations has not yet been well established. This study uses a novel experimental set-up to examine and compare the effects of light touch and cane use on walking stability.

METHODS: Five persons with post-stroke gait dysfunctions (age 64 ± 7.2 yrs) and 5 age-matched healthy controls (age 69 ± 5.1 yrs) walked on a servo-controlled self-paced treadmill mounted on a 6-degree-freedom-of-motion platform while viewing a 3D-animated virtual reality scene that was coupled to the instantaneous speed and surface motions. All participants walked along a 40m level virtual path at comfortable (self-paced) speeds. The instructions given were, in random order, to not touch (NT), to lightly touch (T) a horizontal sensor bar with their index fingertip (dominant or non-paretic finger) or to use a specially designed, instrumented cane (C) as they walked. The horizontal bar was instrumented with a load-sensor strip to ensure that subjects did not touch the bar with more than 10N of force. The cane was affixed onto either side of the self-paced treadmill with a ball-joint mounted onto a triaxial force transducer. Gait variability was quantified as the % coefficient of variability (CV) for stride duration and compared across the 3 sensory conditions (NT, T & C) between the 2 groups of subjects (stroke vs controls).

RESULTS: As expected, the mean CV's of stride duration were higher in people with stroke compared to healthy older adults regardless of sensory condition. Gait stability increased under enhanced sensory conditions (T/C vs NT), as revealed by a reduction in stride duration CV across both the paretic and non-paretic limb, ranging from 15 to 28%. In 3 of the 5 subjects with stroke, gait variability was lowest in the light touch (T) condition. Additionally, average gait speeds increased in both the T and C conditions, as compared to the NT condition. Similar trends were observed in the healthy controls, but 2/5 showed an increase in stride variability and decrease in gait speed under enhanced sensory conditions (T/C).

CONCLUSIONS: Enhanced somatosensory input appears to impact positively on gait stability in people post-stroke, as shown by a decrease in stride variability with light touch or cane use. This improved gait stability with tactile input was further evidenced by a concomitant increase in gait speed. On the contrary, in some healthy older adults, gait can become less stable with the additional sensory input as indicated by higher gait variability in one or both touch conditions. These findings are consistent with previous work [2] showing that the integration of additional sensory input or the greater attention associated with the additional input may hinder gait which is already optimal or stable in healthy subjects. Additional somatosensory input may therefore provide either beneficial or detrimental effects on gait stability depending on an individual's age or pathology-related deficits. The results from a larger group of healthy older subjects and people with stroke will be further analyzed and presented.

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Gait variability associated with extended periods of walking activity in patients with sub-acute stroke

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INTRODUCTION: Clinical assessment of ambulatory function soon after stroke is an effective approach to identify possible impairments to motor control and guide subsequent therapeutic practice [1]. However, the challenge with these assessments is that they are often brief in duration and restrict the patient to short bouts of walking activity. In our previous work [1,2], we have noted an increase in interlimb dyscontrol (gait symmetry) during periods of extended walking compared to a standard clinical assessment. As a result, it is our belief that brief clinical evaluations of gait likely may not always reflect nor challenge a patient sufficiently to reveal potential links between the severity of underlying neurological deficits and measures of gait variability. The purpose of this study is to examine step-by-step changes in gait variability during extended bouts of walking in patients with stroke.

METHODS: Five inpatients with sub-acute stroke were observed using a novel wireless measurement instrument called Accelerometry for the Bilateral Lower Extremities (ABLE), while performing a Six Minute Walk Test (6MWT). Foot-off and foot-contact events were determined for each step taken over the duration of the walk (data sampled at a rate of 50 Hz). To evaluate changes in stride-time variability over the duration of the walk paired t-tests were conducted between the initial and final 30m. In addition, cadence and temporal symmetry were also calculated.

RESULTS: Patients walked with an average velocity ranging from 0.67-1.54 m/s. All subjects walked for the entire duration without pausing except for one, and one patient required an assistive aid while walking. Preliminary results demonstrated that, on average, there was a significant increase in stride time variability between the initial 30m and the final 30m of the 6MWT. Specifically, four of the five patients demonstrated a mean increase of 93.8% in the coefficient of variation of stride time in the paretic limb, while the non-paretic limb demonstrated a mean increase of 30%.

CONCLUSIONS: It appears that impairments to gait control present during brief ambulatory assessments may be exacerbated over extended periods of walking activity, particularly in the hemiparetic limb. These results do not appear to be linked to stroke severity. Such increases in gait variability may be attributed to factors such as fatigue. Contributing to previous studies on effortful activity and spatiotemporal parameters of gait [1], the current study highlights the need to promote extended, continuous ambulatory monitoring in patients with stroke. For example, continuous, step-by-step monitoring of walking can provide a clearer understanding of changes to hemiparetic gait over time and also uncover potential barriers that may be faced as patients transition to community setting.

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Relationship between standing and walking asymmetry among stroke survivors

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INTRODUCTION: Previous research has revealed that stroke survivors demonstrate weight-bearing asymmetry during standing balance and walking [1,2]. Typically, increased loading of the non-paretic limb is observed due to reduced muscle strength, poor coordination and impaired sensorimotor control on the paretic side. However, some stroke patients may favour their paretic side [1,2]. Increased loading to one side may expose these individuals to a higher risk of falling and secondary musculoskeletal consequences. The purpose of this study was to examine the relationship between standing balance symmetry and temporal and spatial gait symmetry among stroke survivors.

METHODS: Fifty-five stroke survivors (62.8 $\pm$13.5 years old and 3.0 $\pm$ 2.5 years post stroke) completed 30 sec of quiet standing on a force platform with their eyes opened and feet in a comfortable position. Participants were categorized into groups according to side of asymmetry during standing: non-paretic, paretic or symmetric. The degree of standing balance asymmetry was determined by the mean mediolateral (ML) centre of pressure (COP) position. Three walking trials were performed in each of two conditions (preferred and fast speed) over a GAITRite® walkway system. Gait symmetry ratios were calculated as paretic/non-paretic for swing and stance time. Overall temporal (swing/stance) gait symmetry is the ratio of paretic (swing/stance) to non-paretic (swing/stance). A one-factor ANOVA was used to compare gait symmetry measures between standing symmetry groups and correlations were performed for comparison of standing ML-COP to gait symmetry measures.

RESULTS: For all participants, standing mean ML-COP position was positively associated with overall temporal gait symmetry ($r=0.294$, $p=0.03$), but not swing ($r=0.015$, $p=0.914$) and stance symmetry ($r=0.06$, $p=0.663$). Mean overall temporal symmetry scores for the paretic, symmetric and non-paretic groups are 1.32, 1.18 and 1.47, respectively. The main group comparison did not reveal a significant difference ($p=0.258$), however there was a trend towards a difference between the symmetric and non-paretic groups ($p=0.118$). Swing and stance gait symmetry scores were not significantly different across symmetry groups for standing balance ($p=0.460$ and $p=0.296$). Step length symmetry revealed a main effect across symmetry groups ($p=0.033$). A post hoc analysis indicated a contrast between the non-paretic and paretic groups (1.054 vs. 0.874, $p=0.014$).

CONCLUSIONS: Standing balance symmetry appears to be related to overall temporal gait symmetry indicating that those who increase loading on the non-paretic limb while standing use the same strategy in walking. Interestingly, on average, all participants showed gait asymmetry toward the non-paretic limb regardless of the side of standing asymmetry. Stroke patients who favour their paretic side during standing are likely to show a greater step length asymmetry. Continued study may reveal factors leading to standing balance and gait asymmetry; therefore both symmetry measures need to be considered in rehabilitation treatment plans.

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Effects of haptic information on postural stability and coordination post-stroke while walking in a virtual environment

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INTRODUCTION: Stroke can cause locomotor impairments including decreased postural stability and coordination. A cane is often provided for gait rehabilitation to improve stability by providing additional mechanical support and sensory information. Haptic information is a form of proprioceptive input that is generated by contact with an external, stable surface. Haptic input has been shown to improve standing postural stability in healthy and neurologically impaired populations [1-3]. This study investigates postural control, by examining centre of mass (COM) stability and coordination, in persons post-stroke while walking in a virtual environment (VE) and using either haptic information or an instrumented cane. We hypothesize that the haptic information will improve postural stability and coordination as much as the cane and that both walking with the cane and with additional haptic information will result in improved COM control compared to walking with no aid.

METHODS: Participants include those who have had a uni-lateral stroke, are able to walk 40m without the use of a cane or additional support, and have full sensation in the fingertips of their non-paretic hand. Age-matched, healthy control participants are included to compare the differences between stroke and healthy individuals. The conditions involve walking 40m on a self-paced treadmill in a VE over a level path at a comfortable, self-selected walking speed. Participants are instructed in a random order to not touch, lightly touch a sensor-strip (haptic condition), or to use the cane while walking. Haptic information is generated by touching a horizontal load-sensor strip at fingertip height with the non-paretic (stroke) or dominant (control) fingertips. The cane is attached with a ball-joint to a tri-axial force transducer and adjusted to a comfortable height. Postural stability is defined by the co-efficient of variation of the centre of mass movement during each stride, and averaged over 40 strides (20 strides/leg). A phase-plane plot of COM velocity versus position during 40 continuous strides (20 strides/leg) was generated and postural coordination is defined as the mean area under the curve.

RESULTS: Preliminary results show decreased stability and coordination in the stroke group compared to the controls. The haptic information seems to improve vertical stability and coordination in the stroke group but does not improve lateral stability in the stroke group as it does in controls. The haptic condition shows the best lateral and vertical coordination for the stroke group whereas the cane condition shows the best lateral and vertical coordination for the control group. Future analysis will include more participants to gain a better understanding the effects of haptic information on postural stability and coordination post-stroke.

CONCLUSIONS: Haptic information seems to improve postural stability and coordination during walking post-stroke but may be used differently compared to healthy controls.

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Gait asymmetry in the subacute and chronic stroke populations

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INTRODUCTION: Improvements in gait post stroke can be made with rehabilitation [1]. However, significant deficits that may remain at discharge result in continued walking dysfunction for the patient. The great effort required to walk may lead individuals to restrict their level of walking, leading to further decline in both the amount and quality. One gait parameter that may capture the decline in the quality of walking is temporal symmetry [2]. A cross-sectional analysis of subacute and chronic stroke patients was used as a preliminary step to investigate how gait asymmetry changes over time in the post-rehab period.

METHODS: The analysis was completed using a database of clinical and research measures for 68 subacute and 151 chronic stroke patients. This included Chedoke McMaster Stroke Assessment (CMSA) scores (a measure of motor impairment) and spatiotemporal gait parameters measured using the Gaitrite Mat™. Swing and stance temporal symmetry of preferred-pace gait were calculated. Individuals were classified as symmetric or asymmetric with respect to a 95% confidence interval around the mean symmetry of 21 healthy individuals. Patients were grouped according to months post-stroke as follows: 0-3, 3-12, 12-24, 24-28 and greater than 48 months.

RESULTS: The percentage of individuals classified as symmetric or asymmetric within each time group for swing and stance symmetry is illustrated in Figure 1. Chi square analyses revealed that the distributions of swing (p=0.01) and stance symmetry (p <0.01) were not random. More specifically, the data revealed a greater prevalence of gait asymmetry in those individuals in later stages post-stroke. Two-way ANOVAs computed on velocity, CMSA leg and foot scores revealed a significant main effect associated with symmetry classification (symmetric versus asymmetric). However, unlike prevalence of asymmetry, there was no significant main effect for time post- stroke. Interaction of time post-stroke and swing symmetry classification was significant for CMSA foot scores only (F=3.03, p=0.02.)

CONCLUSIONS: This preliminary, cross-sectional analysis indicates that gait asymmetry (swing and stance) may worsen over time post-stroke. By contrast, gait velocity and severity of motor impairment does not appear to change over the same time period. It appears that the quality of a stroke survivor's gait may worsen in the post-rehab period. A prospective, longitudinal study is warranted to investigate this further.

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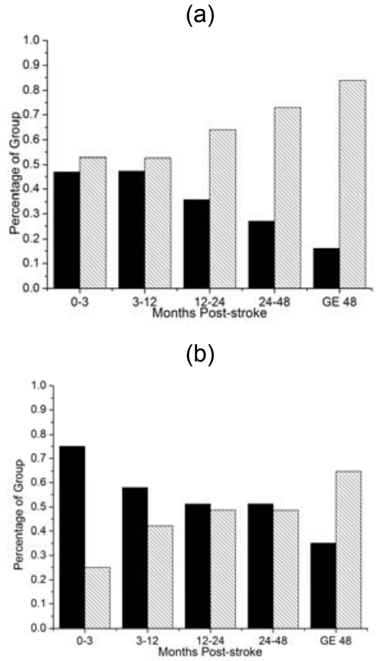

Fig.1 Percentage of individuals in each group classified as symmetric (solid bars) and asymmetric (hatched bars) (with respect to a 95% CI around the mean swing symmetry of 21 healthy individuals) in (a) swing time and (b) stance time.

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Head stabilization: one dimension of balance control during walking post-spinal cord injury

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INTRODUCTION: During walking, healthy individuals aim to minimize perturbations to the head in order to acquire accurate sensory inputs to the visual and vestibular systems and maintain balance control. Research suggests that head stabilization is optimal at self-selected walking speeds and occurs through attenuation of linear accelerations from the pelvis to head [1]. Following a spinal cord injury (SCI), individuals lack the walking balance control seen in healthy persons; however, the impact of SCI on the ability to achieve head stabilization is unknown. Clinicians traditionally introduce assistive devices (ADs) to compensate for these balance deficits. However, ADs offer artificial, externally-controlled stability restricting the opportunity for an individual's CNS to relearn normal balance strategies. Therefore, this study investigated the effect of ADs on walking balance post-SCI. The ability to reduce upper body accelerations and preserve head stability with and without ADs may provide insight into the CNS's solutions to walking balance deficits after injury.

METHODS: Seven persons with motor incomplete SCI (43.4 ± 15.6 years, 5 males) performed two 30-second walking trials at self-selected speeds on a split-belt instrumented treadmill: first with their usual ADs, then without. Motion analysis data were acquired continuously during trials. Step-by-step 3D linear accelerations of the pelvis and head were analyzed across conditions for each participant. Root mean square of accelerations were calculated, then subsequently used to determine attenuation coefficients, representing the ability of the individual to reduce accelerations from the pelvis to the head [2]. Larger coefficients indicated greater attenuation.

RESULTS: All individuals exhibited severely compromised walking speeds ranging from 0.12 to 0.6 m/s. A large continuum of upper body acceleration strategies was detected with each person exhibiting unique patterns. Attenuation coefficients across participants and directions varied from a 0.120% change to a 11,035% change between walking conditions. Specifically, two persons demonstrated greatly increased attenuations in all directions when using walkers, while two others exhibited larger head than pelvic accelerations in all directions both with and without walkers. One individual attenuated extremely well both with and without a cane. In contrast, two persons showed no improvement in attenuation in any direction with canes, exhibiting substantially increased head accelerations both mediolaterally and vertically in one case. Proprioception and light touch status were not factors impacting performance.

CONCLUSIONS: Walking evaluations without an AD allow for testing of an individual's neural control strategy in coping with his/her SCI-mediated deficits. The heterogeneity of acceleration strategies measured here manifest in uniquely observable walking patterns such as rigid, highly variable, or asymmetrical gait. Future work should continue to investigate additional mechanisms and predictors underlying motor control solutions in a person's attempt to recover balance.

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Comparative study between left and right stroke using gait parameters

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INTRODUCTION: Gait rehabilitation is a goal for stroke rehabilitation[1]. We present the results of gait parameters study depends of stroke localisation, right or left.

METHODS: We use RSScan force platform for assessment gait parameters: CA-contact area cm, F-maxim force N, L load rate N/cms, I-impulse Ns/cm, FA-foot axis angle ^{0}, ST-subtalar joint flexibility cm at heel region(medial heel HM and lateral heel HL) before rehabilitation programm[2]. Each parameters in relation with stroke localisation right hemiplegia(RH) or left hemiplegia(LH).

RESULTS: In LH all parameters are lower than right side so average value were: F 744,3N, L 2,10N/cms, I 91,7Ns/cm, CA 133,6cm. FA endorotation/supination on left side(LS) and pronation/exorotation on right side(RS). The heel load during contact phase is on HL or HM for LS and HM or HL for RS, that means exist a compensatory reaction from health side. In RH we observed F 1086N, L 1,19,N/cms, I 965Ns/cm, CA 171,4cm. FA-endorotation/supination of RS and supination on LS. Heel load are symetric on bilateral side, right and left, and we observed a high loading on HL.

CONCLUSIONS: Motor deficit is lower to RH than LH and gait parameters are lower on plegic side than health side also in RH and LH. Gait assessment [3] help early begining of rehabilitation, depends on side of stroke.

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Effects of a gait and mental dual task in vestibular subjects

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INTRODUCTION: Vestibular subjects show slower and unsteady gait [1] and increased interference when carrying out a secondary cognitive task while standing [2]. So far, no studies have investigated dual task behaviour during gait, which is often more impaired than standing in vestibular patients in a late phase of recovery. The aim of this study is to assess gait and cognitive performance in a group of unilateral vestibular subjects in a double task (DT) paradigm.

METHODS: 14 patients with unilateral vestibular iporeflexia or areflexia due to neuronitis, previously assessed by a neurotologist, were included (mean age 45, range 32-63 years, 8 female, 6 male). Cases with other balance, gait and cognitive disorders were excluded. We also excluded elderly subjects (more than 65 years) to rule out age related impairments. Mean time elapsed from the acute phase was 5.1 months. Disability was assessed by DHI questionnaire. An age and sex matched control group of 17 healthy subjects was also assessed. The DT consisted of walking at self selected speed back and forth in the laboratory along a 8 meters path, while backwards counting from a random three digit number. Each task was repeated in single task (ST) condition; the cognitive ST was carried out while sitting. Each task was performed during one minute and the order was randomised. No task was prioritized. Gait analysis was carried out by a STEP 32 system (DEM Italia). The gait parameters considered were: cadence (C) expressed as cyc/min, foot contact (FC), double support (DS) and swing (S) expressed as percentages of gait cycle. The cognitive task was assessed by the number of right figures (RF) enumerated. Intra and between group statistical analysis was done with paired or independent t-test accordingly; between group cognitive analysis was not carried out because considered unreliable in small groups.

RESULTS: Vestibular group: DHI median 38, range 20-80. C: ST 51.9±4.7 cyc/min, DT 49.1±6.3 cyc/min*. FC: ST 37.9±3.9%, DT 40.9±4.5%*. DS: ST 22.8±4.6% DT 26.3±4.5%*; S: ST 38.5±2.3%, DT 36.7±2.2%*. RF: ST 22.9±10.9, DT 17±9.3* Control group. C: ST 53.2±4.6 cyc/min, DT 51.3±4 cyc/min *. FC: ST 36±5.6%, DT 37.8±5.3%*. DS: ST 23.1±4.5%, DT 24.4±4.7%*. S: ST 38.4±2.2%, DT 37.6±2.4%*. RF: ST 22.5±9.3, DT 19.78±9. (*$p<0.01$ for paired data).

CONCLUSIONS: Both vestibular and control subjects had a significant change of gait parameters between ST and DT, showing a more conservative gait during DT; the vestibular group showed a wider trend. Cognitive performance worsened significantly only in the vestibular group. No gait significant differences between groups were found. Vestibular subjects, even if in a late recovery phase, show limited attentional resources in a gait and mental DT and give attentional priority to gait task.

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Where is the "straight ahead" in unilateral vestibular loss?

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INTRODUCTION: Patients with vestibular loss are primarily concerned with balance and gait problems including head and trunk tilt and walking trajectory deviation to the lesioned side. Such asymmetries remain several months after vestibular loss. Postural and locomotor deviations are attributable to changes in perception of self orientation in space. The aim of this study was to characterize changes of the representation of body orientation after unilateral vestibular loss.

METHODS: Experiments were carried out on 21 Menière's patients. All patients underwent unilateral vestibular neurotomy, 10 on the right side (Right vestibular neurotomy: RVN) and 11 on the left side (Left vestibular neurotomy: LVN). They were examined 2 years after surgical treatment. Patients' performances were compared with those of 10 healthy controls. Participants sat in darkness, facing a luminous rod that could be simultaneously rotated and translated. Experiments were performed both in the horizontal and in the frontal planes. The subjective straight-ahead (SSA) was investigated using a method disentangling lateral shift and lateral tilt components. In the horizontal plane, the participants were required to align the rod straight ahead of their body midline. In the frontal plane, they were asked to align the rod with the axis of different body parts (head and trunk).

RESULTS: Analysis of SSA clearly showed distinct results according to the side of the lesion. Patients with LVN had a contralesional lateral shift of the SSA in the horizontal plane. This error was confirmed in the frontal plane, for the head and for the trunk. By contrast, for patients with RVN, the representation of the body midline location was accurate and did not differ from that of control subjects.

CONCLUSIONS: The present study shows that the representation of body orientation is impaired after unilateral vestibular loss. Deviations are observed in the horizontal as well as in the frontal planes. Interestingly, only patients with left vestibular loss were concerned with changes in perception of self orientation in space, which gives evidence for a vestibular asymmetry in healthy subjects. The relationship between such changes in self-representation and postural-locomotor deficits remains to be explored.

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Examination of vestibular neuronitis patient's Body Tracking Test

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INTRODUCTION: Body Tracking Test (BTT) is a testing method of the dynamic body balance function wherein movement of the center of gravity in accordance with a moving visual target stimulus is examined to evaluate the tracking function of the body. We enforced BTT to the vestibular neuronitis patients until now, and have considered the dynamic body balance function. As a result, by stabilometry test, the center displacement of X-direction average of body sway was displaced to the affected side at the time of the eyes closed of time with spontaneous nystagmus. Moreover, antero-posterior BTT carrying out at the period, it turned out that the center displacement of X- direction average of body sway is displacing and tracking to the unaffected side contrary to stabilometry at the time of an eyes closed. This time, the change of stabilometry and the change of BTT by passage of a vestibular neuronitis were considered.

METHODS: They are 30 examples, which were diagnosed as the vestibular neuronitis in the Department of Otolaryngology in Toho University medical center Sakura hospital, and were undergoing hospital treatment. Although gaze nystagmus was noted, inspection was enforced when a standing position posture was possible. Test was conducted one week and one month afterward at the time of the first medical examination. Tests used stabilometry test at the time of eyes closed, and BTT of the constant speed stimulus of antero-posterior direction. The locus length,an area, and the center displacement of X-direction average of body sway of stabilometry test of eyes closed and the statokinesigram of BTT of antero-posterior direction and the center displacement of X-direction average of body sway were used for data analysis at the time.

RESULTS: With passage of the time of a vestibular neuronitis, the tendency for the locus length and an area of an eyes closed stabilometry test to become small was seen. Similarly, the tendency for the center displacement of X-direction average of an eyes closed Stabilometry test and BTT to become small was seen with passage of the time of a vestibular neuronitis. However, these results showed the difference by the affected side. Variation was large when an affected side was the right.

CONCLUSIONS: In the vestibular neuronitis, the lateral difference was shown in convergence of the body sway and BTT in the process which equilibrium disorder recovers by the difference in an affected side. It seems that this result is based on the difference in the stability of a certain lateral originally of man. I thought that the difference in stability on either side would be related to an able leg and the axopodium (non-able leg).

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Peripheral vestibular damage causes impaired navigation tasks on memorized routes in humans

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INTRODUCTION: A parietofrontal network, which is supposed to reflect the spatial imagery components of the topographical task, is activated during both mental navigation and map navigation tasks. The neural substrate for navigation is also composed by a right hippocampal area and by the parahyppocampal gyrus. The role of the vestibular system for navigation and spatial memory has been extensively investigated in animals but not in humans. Significant spatial learning and memory deficits were shown in patients with bilateral vestibular failure after bilateral vestibular neurectomy as compared to 10 healthy controls [1]. The hippocampus was the only area of the brain to show such atrophy correlated with the degree of impairment in spatial memory. Moreover the patients had similar general intelligence before and after the loss of vestibular function. These data suggest that an isolated hippocampal atrophy manifests due to a chronic lack of vestibular input in humans. A small number of studies in which cognitive function is investigated through a form of motor activity to which the vestibular reflexes are known to contribute, such as walking have been proposed [2,3]. Patients with unilateral vestibular neurectomy exhibit more difficulties with “path integration tasks” in which they have to learn to execute a specific trajectory through the environment with different visual conditions than controls. As a further contribution to the field of this research, the aim of this study was to examine whether walking with eye closed along visually-memorized routes and after actual navigation on them with eyes opened was significantly different in well-compensated labyrinthine-defective patients if compared to controls.

METHODS: Fifty labyrinthine-defective patients and fifty controls were invited to visually memorize three different routes (a triangle, a circle and a square) on a carpet and then to walk along them with eye closed clockwise and counter-clockwise (mental map navigation). The same test was then repeated with eye open (actual navigation) and again with eye closed (mental navigation). Execution time was recorded in each test. Corsi block test and a psychiatric questionnaire completed the neuropsychological examination.

RESULTS: Labyrinthine-defective patients showed higher levels of anxiety and depression and perfomed Corsi block test with more difficulties than controls. Patients spent more time than controls in the first and third session (eye closed). No difference was recorded between clockwise and counter-clockwise navigation tasks both in patients and in controls. Patients showed a greater improvement in the third navigation task than controls.

CONCLUSIONS: Walking on memorized routes in non-visual condition is impaired by a peripheral vestibular damage, even if patients are well-compensated. This impairment could be due to a defect of the visuo-spatial short term memory. A new posturographic test will be proposed in order to evaluate the navigation ability.

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Poor postural stability in children with vertigo and vergence abnormalities

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INTRODUCTION: Kapoula & Le [1] suggested that deficits of vergence can influence postural control via the efferent and afferent proprioceptive signals. In this study we explored postural control in 28 children (mean age 11.2 ± 2.7 years) with vertigo, with normal vestibular function but with vergence abnormalities assessed with orthoptic tests. Data were compared with those found out from a group of 19 normal children of comparable age (mean age 11.6 ± 2.2 years)

METHODS: Posturography platform (TechnoConcept) was used to examine posture in quiet stance; child was asked to fixate a target at his/her eyelevel at 40 cm or at 200 cm either with eyes open (vision condition) or with eyes covered by a black mask (no vision condition).

RESULTS: Postural control in children with vertigo and vergence abnormalities is distance dependent as in normal children. The vision and non vision condition influences posture particularly at near distance: indeed for both groups of children RQ values are significantly larger at near distance. Importantly, values of all parameters of posturography are significantly higher in children with vertigo than in control children.

CONCLUSIONS: We suggest that even malfunctioning, vergence capability is important to improve postural stability at near. Consideration of different visual dependency in children than in adults [2,3] has to be moderated given that RQ values reported in both groups of children are similar to those observed in adults [4]. Finally, the impairment on the postural control in children with vertigo and vergence abnormalities could reflect the importance of correct vergence information for a good control of postural gaze. Alternatively, poor postural control in these children could be also due to immaturity of compensatory mechanisms using vestibular, somatosensory inputs, and/or cerebellar processes controlling postural stability

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People with vestibular dysfunction do not require increased attention for step initiation

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INTRODUCTION: In patients with vestibular disorders, attention plays an important role in the sensory integration process for balance, as shown by increased postural sway. This study will expand upon this research by examining if attention also adversely affects the ability of people with vestibular

Condition	Onset of FPA (ms) VEST	Onset of FPA (ms) CON	LO (ms) VEST	LO (ms) CON
SSRT	231 (50)	219 (32)	453 (101)	423 (44)
CSRT	239 (45)	237 (46)	466 (92)	439 (55)
CSRT+ATT	304 (55)	301 (60)	550 (87)	527 (63)

Table 1. Mean (standard deviation) Onset of First Postural Adjustment (FPA) and time of foot Lift Off (LO) for subjects with vestibular dysfunction (VEST) and controls (CON) for 3 task conditions

disorders to step quickly, which may have implications for risk of falling.

METHODS: Twelve patients with vestibular dysfunction (VEST, mean age: 50±7 y) confirmed by caloric and rotational vestibular testing and 16 control subjects (CON, mean age: 37±11 y) participated. Subjects performed a visually-cued step initiation task based on a measure of selective attention (ATT) which assesses the ability of subjects to attend to salient cues while ignoring misleading cues. Subjects stood with each foot on a separate force plate and viewed a monitor that provided them with directional arrow cues (← or →) that appeared on the left or right side of the monitor. In response to the cue, subjects stepped laterally in the direction that the arrow was pointing. In the simple step reaction time (SSRT) condition, all arrows pointed in the same direction. In the choice step reaction time (CSRT) condition, left arrows appeared on the left side of the monitor and right arrows appeared on the right side, in random order. Finally, in the CSRT+ATT condition, right arrows appeared on the left side of the monitor, and left arrows appeared on the right side. The CSRT+ATT task requires greater attentional processing because the subject must inhibit a potent step response toward the side of the monitor in which the arrow was located. The time from the stimulus to onset of the first postural adjustment (FPA), and from the stimulus to liftoff (LO) of the stepping foot were computed by analyzing the vertical ground reaction force curves from each force plate. Data were pooled across left and right steps because there was no difference between them. The effects of subject group and attention task condition were examined using a mixed factor repeated ANOVA.

RESULTS: The ability of the task to engage greater levels of cognitive processing required for stepping was demonstrated by an increase in time to initiate the FPA and LO in the CSRT+ATT condition compared with the SSRT and CSRT conditions ($p < 0.001$, Table 1). There was no difference in FPA and LO between the SSRT and CSRT conditions ($p > 0.18$). There was no difference in step initiation times between subjects with VEST and CON ($p = 0.30$).

CONCLUSIONS: The findings suggest that vestibular dysfunction does not affect step initiation to the same amount as sensory integration tasks. In addition, there does not appear to be greater attention required by the VEST subjects during performance of this task. A possible explanation is that this group of VEST subjects was relatively well compensated, as their posturography scores were no different than the CON subjects.

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Visual vertigo and vestibulopathy: II. Oculomotor findings

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INTRODUCTION: There is a high incidence of visual vertigo (VV) in patients with vestibulopathy. Patients with VV experience dizziness when they are exposed to dynamic ocular inputs [1-3] and therefore their activity level is limited. Despite the high incidence, the physiological patterns accompanying VV are not clear and the treatment protocol is not well defined. The main goals of this study were to compare oculomotor responses induced by nystagmus in different postures between subjects with and without VV and/or vestibulopathy.

METHODS: Ten people with vestibulopathy and VV, 11 with only vestibulopathy but no VV, and 10 age-matched healthy controls participated in the study. All subjects completed questionnaires specific to VV. The vestibulopathy group included subjects with unilateral vestibular deficits who responded negatively to the VV questionnaire, while BPPV, acute labarynthectomy (chemical or surgical), Menier's disease, bilateral vestibular pathology, ocular pathologies, and other neurological or significant orthopedic conditions were excluded. We investigated the oculomotor responses with 2-dimensional videooculography (2D-VOG) as they were exposed to dynamic visual inputs consisting of vertical bars swiping across a screen (towards the affected ear or to the opposite) at a speed of 20deg/sec. Measurements were done in 3 different postures: sitting, standing with feet together (Romberg stance), and tandem stance on the floor under 2 different visual conditions: gazing onto a screen with exposure to dynamic visual inputs first without any fixed target and second with a fixed target on the middle of the screen. Oculomotor responses were quantified as the frequency, mean amplitude and gain of the optokinetic nystagmus.

RESULTS: A significant difference due to both visual conditions (with and without fixed target) was found in the nystagmus frequency between the VV subjects and healthy controls ($P<0.05$). The optokinetic nystagmus gain was significantly higher ($P=0.039$) in the VV (0.9 ± 0.2) and the vestibulopathic (0.9 ± 0.2) groups compared to the healthy control group (0.6 ± 0.1) in the tandem stance posture. The gains were not significantly different between groups for the sitting posture ($P=0.079$), although VV subjects tended to have a higher gain (0.8 ± 0.2) than vestibulopathic subjects (0.6 ± 0.3) or healthy controls (0.5 ± 0.1). There was no significant difference between the three groups in the mean nystagmus amplitude.

CONCLUSIONS: There are some significant differences in optokinetic nystagmus responses between vestibulopathic with VV and healthy subjects. VV subjects tend to depend on visual inputs even though their complaint of dizziness is more pronounced by stimulations of the visual environment. Treating VV subjects by controlled optokinetic stimulation in order to decrease visual dependence might be considered in vestibular rehabilitation.

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Presenting symptoms of otolithic pathology in the vestibular patient

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INTRODUCTION: Patients often voice "typical" vestibular symptoms such as spinning and nausea. Other patients deny spinning but describe vague imbalance, nausea, "being on a boat", or "feeling intoxicated". American astronauts returning to earth frequently voice vague complaints, and they are thought to be related to readjustment of otoliths upon return from microgravity conditions. The taking of an extensive history in a nonleading manner is of utmost importance. Patients may voice a single or multiple complaints, but only report the predominant one during an abbreviated history. Vestibular complaints can be seen in patients with or without head trauma, and after whiplash type injury. It has been suggested that the incidence of otolithic pathology is higher in head injury and whiplash injury. At least one previous study has looked at patients with and without otolithic pathology, and has found that otolithic involvement did not markedly influence balance performance. The patients were grouped according to test results, however, and not by presenting history. Several previous studies have suggested that vestibular complaints related to head trauma or whiplash are more likely to involve otolithic structures, and these patients often present with non-traditional complaints. We wondered if groups of patients with different clinical presentations had suffered pathology predominantly to either semicircular canal or otolithic structures. Our conjecture was that the site of pathology (i.e. predominantly otolithic or SCC) may be identifiable by careful history taking.

METHODS:. We prospectively assessed patients with vestibular complaints, to determine if our hypothesis is correct (i.e. if the site of lesion suggested by history was borne out by diagnostic tests which are able to measure SCC or otolithic pathology).

RESULTS: Results of caloric testing, SVV testing and VEMP testing are compared in our patients with "suggestive" histories suggesting either "semicircular canal" or "otolithic pathology", or both.

CONCLUSIONS: Patients should be classified according to their presenting complaints, as this can potentially suggest site of lesion to an assessor. We suggest that patients also be classified according to head and/or neck trauma, as otolithic vestibular abnormalities are more common in head injured patients.

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Visual vestibular mismatch is suggestive of otolithic pathology

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INTRODUCTION The symptom set of visual vestibular mismatch results from a distorted vestibular signal which does not integrate successfully with environmental information, and the result can be symptoms of vague dizziness and imbalance, often accompanied by other vestibulo-autonomic symptoms. VVM patients deny traditional complaints of true spinning. Often referred to as "supermarket syndrome", VVM can be misdiagnosed as "psychic anxiety" or neurological disease, but is not indicative of either. These atypical vague complaints are akin to those suffered by astronauts returning to earth, who are thought to suffer such symptoms as their otoliths readjust from microgravity conditions. Previous studies have suggested that almost 1/3 of patients suffering vestibular pathology develop VVM symptoms and we regard the development of this symptom set as representative of vestibular pathology but not involving the semicircular canals.

METHODS: Recent studies in our lab have grouped patients as "VVM positive" or "VVM negative" based on their answers to 5 VVM specific questions during history taking. Are you bothered by:

- going on an escalator,
- watching traffic at an intersection,
- being in a supermarket,
- walking in a shopping mall
- seeing checkerboard floor patterns.

We asked 100 patients sequentially referred our series of 5 VVM questions, and grouped them as VVM positive (>2/5 positive) or VVM negative (≤2/5 positive). All patients underwent a full battery of vestibular assessments, consisting of calorics, posturography, vestibular evoked myogenic response (VEMP) testing and rod and frame testing (an enhanced SVV assessment). In a blinded fashion, results of tests were interpreted and a diagnosis of "semicircular canal pathology" or "otolithic pathology" was suggested based solely on abnormalities seen in the tests.

RESULTS: In many patients, results of standard vestibular assessments are normal, but in these patients it is still useful to compare their complaints to the symptoms elicited by calorics, and those generated by posturography. With this technique, it is still possible to try and delineate the source of patients' complaints, even in the face of normal results. The rod and frame test (a test of utricular pathology), and VEMP testing is a measurement of saccular pathology. Our preliminary results suggest a difference in the rate of abnormalities on these tests in patients who have developed VVM symptoms.

CONCLUSIONS: Standard clinical diagnostic tests often show no abnormalities in VVM positive patients and their symptoms often mimic the autonomic symptoms voiced by returning astronauts. This group of patients does not complain of spinning as part of their symptom set, and our hypothesis is that the development of VVM in patients is suggestive of otolithic pathology. Standard clinical tests such as calorics are not of benefit in detecting pathology in these patients but the newer assessment techniques designed to test otolithic pathways (combined with a careful comparison of patients' symptoms to the sensation elicited by calorics and posturography) are helpful in delineating VVM positive patients. We hypothesize that VVM may represent an otolithic correlate of traditional symptoms of vertigo that are generated by semicircular canal disease.

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Intrinsic muscle feet manipulation in carriers of acquired brain injury

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INTRODUCTION: Body stability can be compromised in patients with acquired brain injury due to motor sensitive reduction and plantar support alteration. This results in limitations on the balance control, when this has been requested in an unexpected form**.** The balance in the orthostatic position is unconscious and is based on the intrinsic coordination between the vestibular system, vision, touch information and feet proprioception. Objective: Verifying the effectiveness of the intrinsic muscle feet stretching for increasing of the plantar support and consequent improvement of the orthostatic balance in carriers of acquired brain injury.

METHODS: Nine adult patients who adopted orthostatism without aid of upper limbs have been selected and are in treatment at the Integrated Clinics UNIRP. The first and second samples for baropodometric and stabilometric used a Footwork® baropodometer calibrated with range of 15 seconds for each sample. Data as weight, height, footwear size and the application of the consent form were initially collected. After the first sample was collected the stretching protocol was applied followed by five slides towards posterior-anterior movement performed with a towel positioned on the sole of the foot. The manipulation was carried on with the physical therapist's hands positioned on the medial edge to lateral edge regions pulling from back foot to forefoot at the same time. The time range was five slides at 15 sec. Afterwards the final sample was collected.

RESULTS: Plantar pressure and oscillation speed haven't showed significant improvement statistically after the protocol was applied, however improvement on back foot weight distribution and body oscillation decrease after manipulation was observed. Orthostatic balance presented significant improvement owing to radial detour decrease when compared to pre and post manipulation.

CONCLUSIONS: In the analysis of plantar contact surface it was observed that individuals who underwent the stretching protocol showed plantar support improvement, decreased plantar pressure spikes and shrank anterior–posterior latero-lateral oscillation.

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Structured balance exercises improve dynamic balance ability for community-dwelling older women: a randomized control trial

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INTRODUCTION: Falls are a major problem for older adults, causing many to become dependent on others. Maintaining and/or improving balance ability is crucial in preventing falls. Although many intervention studies have found that exercises can improve/maintain balance ability, the few balance ability tests were arbitrarily selected making it difficult to determine clearly how specific exercise regimens affect balance ability. We confirmed that balance ability consists of static, dynamic and reactive balance ability based on factor analysis [1]. We have developed structured balancing exercises, characterized by perturbing upright posture using a manufactured sponge and a Swiss ball. This study examined the effects of these exercises on either static; dynamic or reactive balance ability in community-dwelling older women.

METHODS: Participants comprised 26 community-dwelling older women in Japan, randomized for age and gait speed to the exercise group (n=13) or the control group (n=13). The exercise group performed structured balancing exercises, in which they maintained upright posture on the sponge and the ball, once weekly for 24 weeks. The control group performed stretching exercises once per month. At baseline and at the end of the intervention, all participants completed balance ability tests. Static balance ability was assessed by measuring postural sway and standing on one leg; dynamic balance ability was assessed by measuring functional reach, timed up and go, and gait; and reactive balance ability was assessed using the EquiTest. We also measured knee and ankle strengths using an isokinetic machine. The data were analyzed using SPSS16.0.

RESULTS: At baseline, the two groups were well matched in physical characteristics and in the results of all balance ability and strength tests. After 24 weeks, timed up and go (p=0.042), cadence of preferred speed walking (p=0.047), and peak torque of knee flexion (p=0.008) improved in the exercise group. In the control group, none of the items showed improvement, except for cadence of preferred walking (p=0.003). There was no correlation between timed up and go and knee flexion torque.

CONCLUSIONS: These results suggest that these structured balance exercises are effective in improving dynamic, but not static or reactive, balance ability. Improvements in dynamic balance ability were not dependent on improved muscle strength.

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Myofunctional therapy in Parkinson's disease patients. A controlled randomized blind clinical study

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INTRODUCTION: Myofunctional Therapy (MT) is a particular type of neuro-psychomotor rehabilitation, finalized to the acquisition of a correct deglutition, through the re-education of the position and movements of the tongue and re-balancing of the orofacial muscles. The aim of this research is to verify whether MT, associated with pharmacological therapy and neuromotor rehabilitation, could positively influence the characteristic symptoms of Parkinson's disease, such as camptocormic posture, bradykinesia, balance disorders, thus improving the quality of life and the safety of this population.

METHODS: The sample was composed by 54 patients (mean age 67.06 years SD 9.55 years) selected according to the following criteria: age < 80 years, stage on the Hoehn-Yahr scale ≤ 3, independent gait (even with aid), clinical and pharmacological stability, cooperative patients, absence of contraindications to motor rehabilitation practice, absence of cognitive decline (Mini Mental Scale Evaluation ≥ 24). The sample was randomly subdivided into three groups of 18 persons: Group A: patients were submitted only to pharmacological therapy; Group B: patients were submitted to group neuromotor rehabilitation (2 times a week, 60 minutes) associated with pharmacological therapy; Group C (experimental): patients were submitted to group neuromotor rehabilitation (2 times a week, 50 minutes) associated with pharmacological therapy, associated with the elevation of the tongue towards the palatine spot (10 minutes), which is the main procedure of MT. Measures from pre and post therapy were analyzed thought repeated measures ANOVA and Tukey-Kramer post-hoc multiple-comparison test.

RESULTS: Hoehn-Yahr scale showed no significant differences (p_{group}=0.767; p_{time}=0.616; $p_{group \times time}$=0.940). Chair stand test showed significant difference within time (p_{group}=0.261; p_{time}<0.001**; $p_{group \times time}$=0.084). All the other measures showed significant differences within time and interaction of group and time factors: Berg balance scale (p_{group}=0.928; p_{time}<0.001**; $p_{group \times time}$=0.004**), UPDRS III (p_{group}=0.597; p_{time}<0.001**; $p_{group \times time}$=0.039*), four meter walk test (p_{group}=0.357; p_{time}=0.007**; $p_{group \times time}$=0.001**), occiput-wall distance (p_{group}=0.694; p_{time}<0.001**; $p_{group \times time}$<0.001**). Post-hoc tests showed

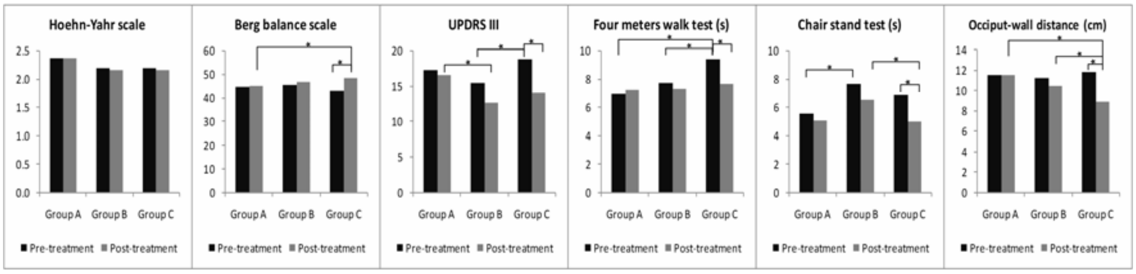

Fig.1 Mean results pre and post-treatment divided by groups

significant differences within pre and post treatment only in group C in all measures but Hoehn-Yahr scale.

CONCLUSIONS: MT, performed with experimental group C, supported improvements in the following areas: camptocormia, meaning the posture in anterior flexion of the body, reducing the risk of falls which is higher in these subjects as the barycentre is shifted forward; balance skills, also during gait. These results clearly show a quality and safety improvement: we therefore wish for the use of MT in the large population of Parkinson's disease patients, in order to improve their posture, make their gait safer and prevent the risk of falls.

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Perception exercises involving the sole of the foot enable the oldest old to better maintain postural balance while standing

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INTRODUCTION: Previous studies have revealed that postural balance while standing is better maintained as a result of perception exercises involving the sole of the foot [1] [2]. However, it has not yet been determined whether such exercises are effective for very old people, i.e., those aged 80 years or more (the oldest old). In this study, oldest-old participants performed a perception exercise wherein they were required to determine the hardness of a surface by using the soles of their feet. We investigated the effects of this perception task on the postural balance maintained while standing, from the perspectives of postural sway and brain activity.

METHODS: The study involved 14 of the oldest old residing in a long-term care facility for the elderly. Written informed consent was obtained from all the participants before the study, and they were randomly assigned to an exercise group or a control group. The exercise group (n=7) performed perception exercises involving the sole of the foot for 10 days. Participants in the control group (n=7) were required to only stand on a rubber surface without trying to determine its hardness. The perception task was performed as follows. First, the participants stood on 5 types of rubber that differed in hardness, and they were required to assess the hardness by using the foot sole and to remember their assessment. The participants were then randomly given each of the 5 types of rubber and requested to determine their hardness over 10 trials. The number of incorrect answers obtained in these trials was determined in order to examine the effects of learning. The centre of pressure (COP), which was determined using a stabilometer (Anima, Japan), was used as an indicator of postural sway. During the task performed on the first and last day of the trial, the brain activity of the subjects in both groups was measured over the frontal lobe by using functional near-infrared spectroscopy (Shimadzu, Japan). To determine the effects of learning, we statistically analyzed the changes in the number of incorrect answers obtained during each exercise session by using repeated-measures one-way analysis of variance (ANOVA). The stabilometric measurements and the extent of forward displacement of the COP before and after the exercises were examined using a paired t-test. In addition, the changes in these measurements before and after the exercises were determined and compared using an unpaired t-test. The level of significance was set at 5%.

RESULTS: For the exercise group, the number of incorrect answers obtained significantly decreased as the trial progressed, and the stabilometric measurements significantly decreased after the intervention. In contrast, the forward displacement of the COP significantly increased after the trial. Within the control group, no significant differences were observed in the stabilometric measurements and forward displacement of the COP. Comparison of the changes in the measurements recorded before and after the trial revealed a significant difference between the exercise and control groups, with the former exhibiting the positive effects of the intervention. The subjects in the exercise group showed an increase in the cerebral blood flow (oxy-Hb) in the dorsolateral prefrontal cortex on the first day of the perception exercise program.

CONCLUSIONS: We demonstrated that the postural balance maintained while standing improves with perception exercises involving the sole of the foot in the oldest old. Further, the changes in the brain activity enable these individuals to better maintain postural balance while standing.

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Physical training in patients with dementia – effects on motor status

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INTRODUCTION: As their non-impaired peers, patients with dementia suffer from age and disease related loss of motor performance. However, demented patients may be even more affected as cognitive impairment is associated with specific motor/cognitive deficits which may cause their 3-fold risk of falling. Despite an increased need for motor training and rehabilitation, political requests had been made to exclude such patients from rehabilitation. The evidence for such claims is limited as only a small number of Randomised controlled trials (RCTs) have been performed, with most of these studies showing substantial methodological limitations [1]. The aim of the present study is to proof the effectiveness of a standardized physical training regimen to improve motor performances in patients with confirmed mild to moderate dementia.

METHODS: 122 geriatric patients with mild to moderate dementia confirmed by established international diagnostic criteria took part in a 3-month RCT. Subjects in the intervention group (IG) underwent a progressive strength, functional, and attentional training within supervised training groups (2x2hrs./week). Subjects in the control group (CG) attended an unspecific low-intensity exercise group (2x1hrs./week). Measurement: Maximal strength of lower limbs was assessed by One-Repetition Maximum for dynamic strength and by a testing equipment for isometric strength for different muscle groups. Functional performances were assessed for transfer abilities (5-Chair rise, stair rise), gait (10-meter-walk-test) and complex motor performances such as Timed-up-and-go-Test and Tinetti's Performance Oriented Mobility Assessment. All measurements were performed at baseline prior to the intervention, at the end intervention period, and at the end of the 3-month-follow-up period.

RESULTS: The study represents one of the largest studies worldwide to examine effects of motor training in patients with dementia. Adherence was excellent in both groups: (Control: 93% vs. Intervention: 94%). No severe training related-injuries or adverse events occurred. Drop out rate was low (17% for 6-month period) for the high-aged, multimorbid sample. All tested functional and strength parameters had been improved by the intervention (Range: $P<0.001$-0.029). Training gains were partly lost during follow-up in the intervention group (Range: $P<0.001$-0.105). The performance of the control group remained at baseline levels during the intervention period and follow up.

CONCLUSIONS: Study results show that patients with dementia achieve clinically relevant improvements comparable to geriatric patients without dementia when trained in an impairment-adjusted setting. Improvement of functional performances achieved in this training intervention may help to defend independence and increase quality of life in this group of impaired patients.

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Biofeedback for training balance and mobility in older adults: a systematic review

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INTRODUCTION: One-third to one-half of the population over age 65 reports some difficulty with balance or ambulation [1]. Balance and mobility disorders can have serious consequences regarding physical functioning (e.g. leading to fall-related injuries) as well as psycho-social functioning. Beneficial effects of balance and mobility-related task exercise interventions have been demonstrated in older adults [2]. Providing the older adult with additional sensory information on their own motion, i.e. biofeedback information, may enhance training effects. Meta-analyses on the effects of biofeedback-based training have been conducted primarily for stroke rehabilitation [3-5]. The present study reviews whether larger improvements are obtained when providing biofeedback information during balance and mobility-related task training in older adults, compared to regular training without biofeedback.

METHODS: After a broad search that was conducted up to September 2008, studies in older adults, i.e. mean age ≥ 60 years, were included when they compared biofeedback-based training of balance and/or mobility to similar training without biofeedback, an educational program or no intervention, and when they used objective measures of balance or mobility as outcomes. The selection of studies and rating of quality, with use of the PEDro scale, was performed independently by 2 reviewers.

RESULTS: Nineteen studies met the criteria for inclusion. Group sizes were small to moderate and quality scores were mostly moderate. Since large heterogeneity existed between studies in the measures and testing conditions that were used to evaluate improvement after the intervention, a qualitative analysis was performed. Three studies provided evidence for a positive effect of training balance on a force plate system with visual feedback in 'frail' older adults on the Berg Balance Scale. Based on the results of 2 or more available randomized controlled trials, evidence for larger effectiveness of training with biofeedback than without biofeedback was found for gait rehabilitation in older patients with stroke and in older patients with an injured lower limb, and for training balance in combination with sit-to-stand transfers in older patients with stroke. However, evidence for similar effectiveness of biofeedback-based and conventional balance training was found in older patients with stroke. No clear evidence was found regarding the long-term (non-) added benefit of applying biofeedback for balance and mobility training and regarding the effects in other populations of older adults.

CONCLUSIONS: Indications exist for positive effects of biofeedback-based therapy, for supporting performance of balance- and mobility-related activities, in the older population. No indications exist for smaller effectiveness of biofeedback-based training compared to regular training.

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Human balance improvement by supplementary information about body tilts

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INTRODUCTION: Balance impairment seen in elderly is frequently related to a slight sensory deficit. To avoid a following postural instability for elderly is recommended to perform exercise and activate their sensory-motor system. It is known that supplementary sensory information about body tilt presented to subject during stance is a common method of balance training. This study examined performance in subjects of different ages over three sensory feedback conditions during stance in order to better understand a stabilizing effect of supplementary information.

METHODS: We tested 12 junior and 12 senior subjects during stance with three sensory conditions: quiet stance with no supplementary feedback, stance with enhanced visual feedback about body tilt, stance with vibrotactile feedback about body tilt. Subjects performed four trials in each of three conditions of stance with eyes open. One trial lasted 50s duration. Body sway in anterior-posterior and lateral directions were characterized by displacement of CoP and by 2D-accelerometers located on the head, the upper trunk (Th4) and lower trunk (L5) level.

RESULTS: The CoP displacement in both directions showed a slight reduction of amplitude during stance with supplementary visual or tactile information about body tilt sensed by accelerometer at L5 level. The improvement of the body balance during enhanced sensory feedback was confirmed also by decrease value of parameter root mean square. Contrary, increase of mean CoP velocity occurred which indicates voluntary control activation in balance control. This is also in good relation to the finding that in conditions with visual or tactile supplementary information, the main frequency range of body sway shifted a little to the increased frequency value. It was interesting that subjects with a sensory deficit may improve their balance control relatively more than healthy subjects.

CONCLUSIONS: Results confirmed the reduction of the body sway in stance conditions with supplementary sensory information. Subjects were able to use the enhanced visual or tactile information about body tilt and improved their balance control during static stance. Furthermore, analysis of the body segment sway during sensory feedback test indicated that it may provide useful information about balance impairment in elderly and should be use also for balance training.

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Visual processing and balance-recovery reactions: development and pilot testing of a "visual training" program to improve change-in-support reactions in older adults

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INTRODUCTION: Visuospatial information about the surrounding environment is required for the control of "change-in-support" balance-recovery reactions that involve rapid limb movement toward handholds or step locations [1,2]; however, aging impairs ability to rapidly process visuospatial information [3]. A computer-based "Useful Field of View" (UFOV) training program has been shown to be effective in improving such processing in older adults [4], and studies of young adults have shown that "first-person shooter" (FPS) video games can have similar benefits [5]. The objectives of this study were to identify a video game that would be suitable for training older adults, and to compare the efficacy of video-game and UFOV training programs in improving the control of rapid reach-to-grasp balance-recovery reactions.

METHODS: To identify a suitable video game for use in the training program, 16 older adults (ages 64-77) viewed video demonstrations of various video games. Questionnaires were used to assess willingness to play and anticipated level of enjoyment. Subjects then tried out three types of video games (realistic FPS, cartoon FPS and fixed shooter), as well as the UFOV program. After each 30-minute try-out, they completed a user-satisfaction questionnaire. To evaluate the training programs, older adults are randomly assigned to either video-game or UFOV training, or to a control group (computerized word puzzles involving no spatial processing). Each group attends two 45-minute sessions per week, for five weeks. Pre-and post-training assessments involve sudden unpredictable platform perturbations. Subjects must grasp a small handhold to recover balance, and the location of this handhold is varied unpredictably prior to perturbation onset. To force subjects to rely on peripheral vision to guide the reach, they are instructed to fixate on a computer screen directly in front of them. In other trials, they are allowed to fixate on the handhold. Motion analysis and EMG measures are used to characterize the reactions.

RESULTS: After viewing the video-game demonstrations, 63% of subjects refused to play the realistic-FPS video game. In contrast, 100% were willing to play the cartoon-FPS video game, enjoyed playing it and said they would be willing to play it again; hence, this game was selected for the video-game training program. The evaluation of the video-game, UFOV and control training programs is currently in progress. Results from the first 12 subjects (ages 64-80) will be presented at the meeting.

CONCLUSIONS: This study will provide new information about the role of visual processing, and the impact of age-related deficits, in the control of balance reactions. Moreover, we anticipate that results will support the efficacy of visual-training programs as viable interventions to improve ability to recover balance. We had expected that subjects would prefer video-game training; however, results to date indicate that most subjects also enjoy UFOV training. Nonetheless, video-game training has other features ("addictive" properties, low cost, potential for self-administration in the home) that may enhance training benefits, subject compliance and cost-effectiveness.

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Does loading at the ankle helps in rehabilitation of gait impairment due to vestibular disorder? - preliminary study

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INTRODUCTION: Integration of normal equilibrium function, space orientation and cognitive function are needed to complete a straight line or circular walking. Also, somatosensory, visual and vestibular inputs play important roles in a constantly varying three dimensional environment to perform a smooth locomotion. However, patients with vestibular disorder, suffer problems on gaiting and falling which eventually affect the activity of daily life (ADL). In order to improve the ADL so that patients will return to their normal life, an early rehabilitation program is needed soon after the primary treatment. We proposed a simple and economical training program by walking while putting on a loading at the ankle. To evaluate the effectiveness of the training, a preliminary study on normal individuals (young adults) were studied walking on straight line (8m) and circle (radius, r=1m) under eyes-opened and blindfolded conditions by means of gait analysis using tactile sensors before and after the training.

METHODS: Participants (young healthy adults, n=7, average age: 23 y.o.) were asked to put on a loading (2kg) on one ankle to perform a walking training on a treadmill for 15 minutes daily, for one week. Gait analysis using tactile sensors installed under both feet were performed before and after the training. Area ratio and coefficient of variation (CVs) of stance, swing and double support were analyzed as gait phase-related parameters. Comparison of means were made using the two-tails t-test, with $p<0.05$ as the criterion for statistical significance.

RESULTS: No significant difference was found between the before- and after-training when walking on straight line neither under eyes-opened nor blindfolded conditions. But, when comparing the after-training category between eyes-opened and –closed, greater area ratio of trajectories of centre of force was found on both the unloaded and loaded feet under eyes-closed condition. Also, CV value of swing of the unloaded foot is greater. On after-training circular gait evaluation, the CV value of stance of both outer and innermost unloaded feet is larger under eyes-closed condition compared to that of eyes-opened.

CONCLUSIONS: Adaptation might have been developed in the somatosensory system during the training program in healthy young individuals that showed no difficulty in completing a straight line gait. However, so far, we have no evidence showing how the adaptation takes place. On the other hand, due to the fact of difference in vestibular input when walking on circle, to maintain a balanced gait under visual input deprivation, the duration of stance is tend to be longer in blindfolded condition. The findings of this preliminary study could be a clue suggesting that propioception contribute to the rehabilitation for unilateral vestibular disorder.

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Automated auditory biofeedback training to enhance postural control and mobility in patients with Parkinson's disease: preliminary results from SENSACTION-AAL

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INTRODUCTION: Impaired postural control and diminished mobility are common among older adults, especially among patients with neurodegenerative disorders like Parkinson's disease (PD). Unfortunately, traditional therapeutic approaches are often not effective at treating these motor deficits [1, 2]. Previous work has demonstrated that auditory biofeedback (ABF) may be used to enhance postural control in patients with bilateral vestibular dysfunction [3]. We speculated that ABF could be applied to augment feedback and treat the motor deficits common in aging and PD and tested the hypothesis that four weeks of training with automated ABF enhances postural control, gait, mobility and health-related quality of life in patients with PD.

METHODS: ABF was integrated into a progressive training program. A 3-D accelerometer (McRoberts) worn on the lower back was used to estimate sway and target positioning as calculated using a PDA. Auditory feedback at target positions (e.g., correct postures or stepping) was provided via headphones or speakers. Subjects participated in 4 weeks of training, 3 times per week, with each training session lasting about 30 minutes. Tasks trained included postural control (sitting and standing), sit-to-stand and stand-to-sit, stepping and reaching. Subjects were tested at baseline and after the completion of the training program. Pre-post testing included the motor portion of the Unified Parkinson's Disease Rating Scale (UPDRS), the Timed Up and Go (TUG), Berg Balance Scale (BBS), postural control (e.g., sway during quiet standing and while eyes closed) and the PDQ-39, a measure of health-related quality of life.

RESULTS: These preliminary results are based on the study of 3 PD patients (H&Y stage II-III; mean age:72 years range 71-73), mean disease duration: 5 years (4-6), and disease severity (UPDRS motor score) of 32.7 ± 15.0. Briefly, we found improvements after training in measures of balance such as the TUG, with an average improvement of 1.2 ± 1.6 seconds (8.2%) from pre test. All subjects had a change of 2 points in the BBS with improvements in tandem standing, one leg stance and changing legs on a step. Two out of 3 subjects improved in postural control (pull test) as measured in the UPDRS with all subjects improving by 2-5 points on this test. Furthermore, anterior - posterior sway during quiet standing with both eyes open and closed decreased (improved) after training. Improvements were also observed in measures of quality of life (PDQ-39) in the mobility domain (average improvement of 3.5 points). All subjects reported less missteps and near falls during the month of training.

CONCLUSIONS: To our knowledge, this is the first time that ABF has been applied as part of a training program. Initial experience using the SENSACTION-AAL paradigm suggests that this mode of therapy is efficacious and worthy of further study. While future work is needed to address many questions, the preliminary findings suggest that patients with PD apparently improve their postural control, mobility and health-related quality of life in response to training with ABF.

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P.338

Could a multimodal sensory substitution system be used to prevent pressure sores during seated posture ?

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INTRODUCTION: Pressure sores represent the main cause of rehospitalisation in paraplegic persons who have no more access to the sensation of pain arising from their buttock. Along these lines, a sensory substitution device [1] could be an appropriate tool to alert them of long-timed overpressures and may help them to avoid such pressure sores [2]. This experiment was designed as a proof of concept to prevent pressure sores with paraplegic persons using an innovative and non intrusive sensory substitution device [3].

METHODS: Buttock pressures are recorded with a pressure map system connected to a laptop that can alert the subject in case of presumable dangerous overpressures, by the mean of a multi-modal feedback system consisting in a simulated vibrating watch. This one is made of a vibrating motor and a switch attached to the wrist and a miniaturized screen (simulated by using a small part of a second laptop screen). Six young healthy volunteers gave their consent to participate to this study. They were comfortably seated in a chair, watching TV and equipped with the sensory substitution device in two control and experimental sessions. In the experimental session, when subject received a vibrating alert, he had to toggle the switch to see the watch screen indicating him the location of the buttock overpressure. He was then required to suppress this overpressure with an appropriate postural reaction (figure 1).

RESULTS: Twenty feedbacks were sent to each subject during the experimental session. In 97.5% of the trials, subjects successfully corrected their seated posture with an appropriate postural reaction that decreased the buttock overpressure previously measured.

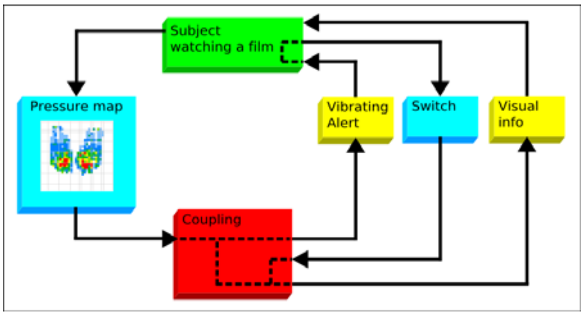

Fig.1 Scheme of the whole biofeedback system ; After having been alerted of a dangerous overpressure by a vibration, the subject toggle the switch to get the visual information about the location of the overpressure.

CONCLUSIONS: The present findings suggest than young healthy subjects can use our pressure sores prevention device to avoid long overpressures while having other perceptual/attentional recreative activities. These encouraging results will allow us to clinically evaluate the efficacy of this multimodal sensory substitution device on paraplegic persons in term of pressure sores prevention.

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A randomised clinical study to evaluate the employment of FES cycling in the rehabilitation of post-acute stroke patients: preliminary results

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INTRODUCTION: Cycling induced by functional electrical stimulation (FES) is an interesting method in the rehabilitation of post-acute stroke patients [1-3]. A randomised, single-blinded, clinical study is ongoing in the Rehabilitation Centre of Villa Beretta to evaluate the efficacy of this treatment.

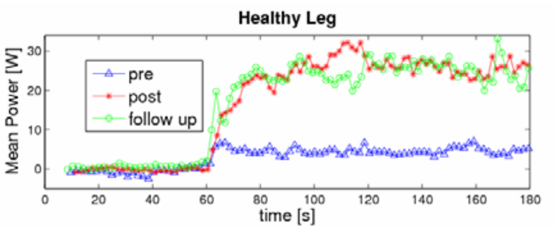
METHODS: The patients are shared in 2 groups: the first performs daily 25 minutes of FES cycling, the second 25 minutes of FES cycling placebo. Quadriceps, hamstrings, tibialis anterior and gluteus of both the legs are stimulated. The trial is carried out on a motorised cycle-ergometer, at 20 rpm. The patients are evaluated before, after the treatment (20 days) and in a follow-up session, by the following tests: Motricity Index, Truck Control Test, Upright Motor Control Test, Walking Test (50 m), Maximum Voluntary Contraction (MVC), Voluntary Pedalling and Sit to Stand.

RESULTS: Up to now 20 patients have been included. 16 patients have already finished the treatment and 5 of them performed also the follow up test. The first FES cycling patient who concluded the treatment learnt to control the standing up velocity; he reduced the pedalling unbalance from 129% (pre-treatment) to 15% (post-treatment) and then was maintained at 12% (follow-up), as shown in Figure 1; finally he increased the force produced by the paretic leg during MVC (table 1).

CONCLUSIONS: All patients of the FES cycling group showed better results than the others. However, a statistical comparison between FES cycling group and placebo group will be performed at the end of the study.

ACKNOWLEDGEMENTS: We would like to acknowledge all the patients involved in the study and Hasomed GmbH for providing the stimulators.

(a)



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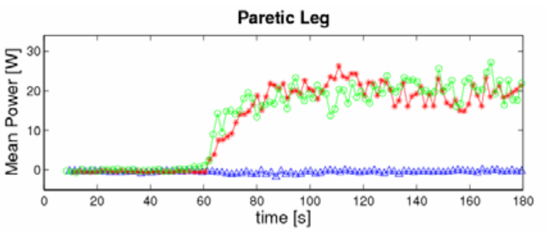

Fig.1 The Mean Power per revolution produced by the healthy (panel (a)) and paretic (panel (b)) leg during the voluntary cycling carried out in the pre post and follow up test.

	Rectus Femoris		Biceps Femoris		Tibialis Anterior	
	paretic leg	healthy leg	paretic leg	healthy leg	paretic leg	healthy leg
Pre-test	27	159	0	46	7	101
Post-test	118	224	57	68	27	34
Follow-up	151	148	88	98	75	101

Tab.1 MVC force produced by the first patient during the pre post and follow up test. The values are in N.

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Balance training positively affects postural sway dynamics and falls risk in type 2 diabetes

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INTRODUCTION: The occurrence of age-related diseases like Diabetes is commonly associated with a general loss of system complexity and related functional capacity that impairs health, well being, and independent living. The decline that occurs in diabetes can be observed across a broad spectrum of performance measures, with particularly strong implications for postural stability and balance. Consequently, older individuals with diabetes are at an increased risk of falling when compared to age matched, healthy individuals.

METHODS: This study assessed the falls risk and balance in older individuals with Type 2 diabetes and the impact balance training has on postural control and falls risk in these individuals. Sixteen individuals with type 2 diabetes and 18 age-matched controls participated (50-75 yrs). The falls risk of all subjects was ascertained using the Physiological Profile Assessment test (Lord et al., 2003) which incorporates measures of simple reaction time (RT), postural sway, sensation, proprioception and lower limb strength to produce an overall falls risk score (range -2 to +4). The postural stability of each subject was also assessed while they stood on a Bertec balance plate. Changes in each subject's center of pressure (COP) as a function of different support surfaces (firm, foam) and vision (eyes open, closed). Differences in the range, variability and structure (using approximate entropy, ApEn) of the COP outputs were measured. After these assessments, all subjects participated in a six week balance training program after which they were re-assessed using the falls screen and static posture tests.

RESULTS: The results demonstrated that the diabetic group had a significantly higher falls risk score (0.82±0.13) compared to controls (-0.12±0.11). The diabetic group also exhibited evidence of neuropathy, and had significantly slower reaction times. Evaluation of the COP data showed that the diabetic group exhibited increased postural sway (increased COP excursion) compared to controls.

The COP output of the diabetic group was also less variable (decreased SD) and more regular (decreased ApEn). Following training, the diabetic group exhibited a significant reduction in their falls risk score (0.11±0.16; p<0.05). This decline was characterized by significant increases in lower limb strength, faster reaction times, and altered COP dynamics. The COP measures of the diabetic group post-exercise were characterized by increased signal complexity and increased variability compared to their pre-exercise values.

CONCLUSIONS: Overall, the results of this study show that balance training has wide-spread positive effects on physiological function for older individuals with Type 2 diabetes. In particular, decreased risks of falling and altered postural sway dynamics were observed. Interestingly, the COP output of the Diabetic group became more similar in terms of complexity/variability to that seen in the age-matched controls, which may reflect that the exercise intervention resulted in increased variability of postural dynamics.

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Parkinson's disease patients can improve gait performance in single and dual task contexts following gait training with music

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INTRODUCTION: Auditory cueing has been identified as an effective strategy in improving spatiotemporal parameters of parkinsonian gait in both single and dual task situations [1], nevertheless, there are a number of limitations associated with conventional auditory cueing including the lack of salience to the individual. There appears to be a definitive need to develop an alternative therapy that, whilst functionally and ecologically relevant, is also significant to the patient. Given the potential for music to facilitate movement in pathological populations [2, 3], music could pose an attractive alternative to current cueing strategies. Work from our laboratory recently indicated that listening to music whilst walking seems detrimental and may impose an attentional load during gait for Parkinson's disease (PD) patients. However, in agreement with the premise of multitask training we theorized that repeated exposure to music during walking might offset any negative effects that were demonstrated upon acute exposure to walking with music. Our purpose was to explore the use of music as a viable training tool for overcoming the walking difficulties that are symptomatic in PD and typically exacerbated in dual task contexts.

METHODS: Twenty-four medicated PD patients recruited from two centres (Lethbridge and Halifax, Canada) were randomised into an experimental (MUSIC; n = 12) and a control (CTRL; n = 12) group. Participants assigned to the MUSIC group walked at a self-selected pace for 30 minutes, 3 times per week for a 12-week period while listening to a preloaded music battery on an MP3 player. The music battery was individualised for each participant, matching music preferences and the cadence of the participants preferred walking speed. The CTRL group continued with their regular activities for the 12-week period. Spatiotemporal measures of gait were assessed pre- and post-intervention. Each participant completed 12 single task (steady state gait) and 12 dual task (serial 3 subtractions) trials, walking 10m at a self-determined velocity under two test conditions; without music and whilst listening to music. Music selections were based on the criteria of enjoyment and familiarity. Spatiotemporal parameters of gait were quantified using custom MATLAB® programs.

RESULTS: The CTRL group demonstrated maintenance or decline in walking velocity across both single and dual task NM trials following the 12-week intervention. In addition, the CTRL experienced a further decrease in gait performance in concurrent music trials. In contrast, participants in the MUSIC group showed a significant improvement ($p < .05$) in walking velocity post-intervention in both single and dual task contexts. Additionally, the MUSIC group maintained gait performance during concurrent music trials. A similar pattern emerged for the parameter of stride length; however, the interaction did not reach significance ($p > .05$).

CONCLUSIONS: Regular walking whilst listening to familiar and enjoyable, cadence-matched music appears to improve functional gait performance across both steady state gait and dual task conditions. In addition, the music intervention may reduce the attentional load imposed by acute exposure to a cognitive distracter. These findings demonstrate the feasibility and benefit of using music accompaniment to augment regular walking programs.

ACKNOWLEDGEMENTS: Funding was provided by the CIHR.

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Electro-tactile tongue biofeedback improves balance in persons with unilateral lower limb amputation

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INTRODUCTION: One way to improve balance control, especially in contexts lacking available, accurate and reliable sensory cues or in individuals suffering from sensory-motor deficits, involves the use of biofeedback in a balance prosthesis. Considering the crucial role played by plantar cutaneous information in the control of upright posture, we recently have developed a plantar pressure-based, tongue-placed electro-tactile biofeedback system for improving postural control [1]. Its principle consists in providing additional sensory information related to foot sole pressure distribution to the user through a tongue-placed tactile output device. The present experiment was designed to investigate whether this biofeedback system could help unilateral lower limb amputees to improve their balance, as a sensory substitution for loss of somatosensory information from the lower limb.

METHODS: Twelve unilateral transfemoral amputees and 12 able-bodied controls voluntarily participated in this experiment. They were asked to stand as immobile as possible with their eyes closed in two conditions of No-biofeedback and Biofeedback. The No-biofeedback condition served as a control condition. In the Biofeedback condition, subjects used a plantar pressure-based, tongue-placed electro-tactile biofeedback system. This device comprises two major components: (1) a plantar pressure data acquisition system as the sensory unit; (2) a tongue-placed electro-tactile tactile output device [2]. Plantar centre of foot displacements were recorded separately under each limb using a plantar pressure data acquisition system.

RESULTS: Compared to the able-bodied controls, unilateral transfemoral amputees exhibited increased centre of foot pressure displacements under the non-affected limb in the No-biofeedback condition, whereas no significant difference were observed either under the prosthetic limb in the No-biofeedback condition, or under both the non-affected and prosthetic limb in the Biofeedback condition. In addition, in unilateral transfemoral amputees, larger centre of foot pressure displacements were observed under the non-affected limb than under the prosthetic limb in the No-biofeedback condition, whereas the Biofeedback condition yielded no significant difference between the centre of foot pressure displacements measured under the non-affected limb and those measured under the prosthetic limb.

CONCLUSIONS: These results suggest that unilateral lower limb amputees were able to integrate artificial plantar pressure information delivered through electro-tactile stimulation of their tongue, as a sensory substitution for loss of somatosensory information from the lower limb, to improve their postural control during quiet standing. Together with a recent study demonstrating the effectiveness of an electro-tactile tongue vestibular substitution system in improving balance in vestibular-defective patients [3], we believe that the present findings could have implications in clinical and rehabilitative areas.

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Changes in gait dynamics in older persons with type 2 diabetes following exercise

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INTRODUCTION: Optimal sensorimotor function is essential of postural control. Unfortunately, impairments in sensorimotor function are commonly observed as a function of aging, inactivity, and with diseases such as type 2 diabetes. Indeed the combination and aging and diseases like diabetes is particularly problematic since older individuals with type 2 diabetes are at greater risk of falls than healthy elderly controls [1, 2]. Abnormalities in gait and posture are strongly correlated with diabetes and the increased risk of falls [2]. The purpose of this study was identify gait characteristics in individuals with type 2 diabetes and their age-matched controls following a 6-week strength and balance training intervention.

METHODS: Thirty-two elderly (50-75) individuals, sixteen with type 2 diabetes and 18 healthy age-matched controls, participated in this study. Participants were asked to perform six straight walking trials at a self-preferred pace on a GAITRite© mat. Following this assessment, all subjects participated in six weeks of thrice-weekly, supervised balance training that included light resistance and balance exercises. After completion of the training intervention, subjects were reassessed on the same measures.

RESULTS: During the initial walking trials, the diabetic group had significantly altered baseline gait dynamics compared to the controls. This was characterized by significantly increased time spent in stance and decreased step and stride length ($p < 0.05$). Following the exercise intervention, the diabetic groups exhibited significant changes in their walking patterns, highlighted by alteration in the percentage of time spent in double support and single support in comparison to the age- matched controls.

CONCLUSIONS: The older individuals with type 2 diabetes adopted a more cautious gait pattern in comparison to the age-matched controls. While the exercise intervention produced changes in the walking patterns of both groups, the changes observed were more pronounced for the diabetic group. Overall the results demonstrate that mild resistance and balance training can have an impact on both older individuals with type 2 diabetes and healthy elderly persons.

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Effect of a 10-week exercise training program on reactive balance control in the frail elderly

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INTRODUCTION: Exercise has been shown to be efficacious in improving balance and reducing the risk of falls in the elderly population [1]. However, evidence regarding the best form that this exercise should take is non-conclusive. Since tango dancing involves rhythmic, off-center balance control, coordination and cognition, it is reasonable to expect improvement in balance abilities in individuals who are active dancers. Clinical improvements in balance self-efficacy, sit-to-stand scores and normal/fast walk speeds have been shown in a group of elderly who participated in a tango dance class as compared to a walking group [2]. To further understand the biomechanical changes which dance training or non-specific walking exercises may contribute to balance control, individual subjects from those two groups of seniors at risk for falls were randomly selected to be examined on their postural responses following unexpected surface perturbations, before and after training.

METHODS: Nine frail elderly subjects (age 62-87) with a previous history of falls participated in a 10-week exercise training program (40 hrs, 2 hr 2x/wk). Five were randomly assigned to a walking group and four engaged in an Argentine Tango dance class. Pre- and post-training, subjects were subjected to sudden tilts (10˚ at 53˚/s) of the support surface while standing in a pseudo-tandem stance posture (mimicking the double limb support phase of walking). These perturbations were performed in multiple directions (toes-up, toes-down, side-up, and combined diagonals) for a set of three trials per direction. Kinematic data were recorded and used in combination with anthropometric measures to calculate the total body center of mass (CoM). Kinetic data were acquired using two adjacent AMTI force plates mounted within the moveable platform. All data were aligned with respect to the onset of platform perturbation.

RESULTS: In general, total body CoM excursion in the horizontal plane was significantly smaller after training (by ~25 mm) in the walking group for all perturbation directions. In contrast, CoM excursion was significantly larger in the tango group after training (by 3-30 mm) in all directions of perturbation except for the pitch plane tilts which showed a similar trend as the walking group. Kinematic analysis of the upper trunk and pelvis showed a reorganization of postural control, particularly in the tango group, whereby both the trunk and pelvis work in tandem to counteract the surface perturbation post-training. Initially, subjects' trunk displacement followed the direction of the surface tilt. Overall, the magnitude of changes in ground reaction force appear to be smaller post-training in the dance group as compared to the walking group, although these differences are small and variable.

CONCLUSIONS: Long-term plastic changes related to posture and balance control are possible in the frail elderly, regardless of the form of exercise or training. Argentine tango dance training appears to result in more compliant postural responses with unexpected, external perturbations, as compared to walking exercises. However, a greater sample size is required before these results can be used as a guide for balance training.

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EEG correlates of postural audio-biofeedback

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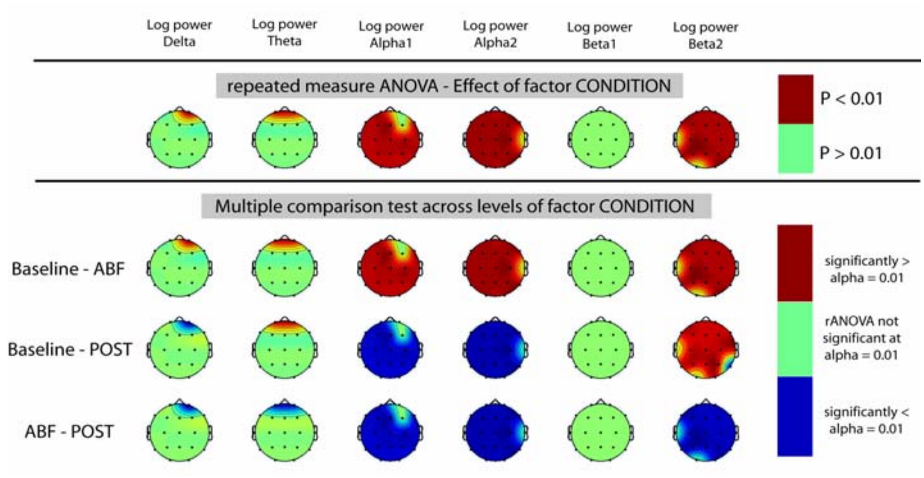

Fig. 1 Statistical results about factor CONDITION

INTRODUCTION: Postural control depends on the integration of multisensory information in the CNS. Audio biofeedback (ABF) systems have been shown to improve postural control, especially when natural sensory information is limited by environmental conditions or pathology [1]. However, the effects of ABF on the CNS and the neural mechanisms associated with its sensory augmentation are still unknown. We present here a novel methodology that we used during simple postural tasks to preliminary investigate such relationships on a single subject basis.

METHODS: We used a portable device for the monitoring of postural oscillations and for the delivery of ABF [2]. The subject was tested prior (CONDITION: Baseline), during (ABF), and after (POST) the delivery of the ABF. In each CONDITION, the subject performed 3 standing TASKS: eyes closed, eyes closed during a cognitive subtraction task, and eyes closed on foam, for a total of 9 trials, 3 min each. At the same time, 19 EEG channels were recorded (Neurowave, Khymeia) at a sampling frequency of 256 Hz. Paroxysmal portions of EEG signals were rejected and ocular and muscular activities were corrected by a mixed Wavelet Decomposition - Indipendent Component Analysis procedure. Remaining EEG portions were epoched (length: 2 s; superposition: 1 s); powers in classical bands (δ, θ, α1, α2, β1, and β2) were calculated for each epoch and log-transformed to gain normality of their distributions. A 2-way (CONDITION x TASK), repeated measures ANOVA was conducted for each *parameter x channel* combination to test for differences among the parameters at a significance level $\alpha = 0.01$. Bonferroni correction for multiple testing was applied.

RESULTS: Significant effects of both factors CONDITION and TASK and of their interaction term were found in a multitude of *parameter x channel* combinations. It has to be mentioned, however, that significant effects of factor CONDITION on α1 and α2 power are widespread over nearly all channels (Fig.1). Post-hoc multiple comparison tests for factor CONDITION revealed that α1 and α2 power significantly decreased from Baseline to ABF and increased again from ABF to POST.

CONCLUSIONS: Since α EEG rhythm is usually thought as a marker of an idling state of the underlying cortices, the present finding can be interpreted as a sign of a generalized activation of the brain during ABF (EEG is sensitive to ABF) and suggests further investigations, including a variation in the methodology to allow a better comparison of the cognitive and sensory contributions to the observed EEG responses.

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Rationale and design of the ParkFit study: a randomized controlled trial to increase physical activity in patients with Parkinson's disease

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Introduction: Many patients with Parkinson's disease (PD) have a sedentary lifestyle, caused by a combination of physical impairments and cognitive dysfunction. Patients should be stimulated to increase their physical activities, for several reasons. First, physical activity has generic positive effects in preventing complications such as cardiovascular disease, diabetes mellitus and osteoporosis. Second, physical activity may have positive effects on PD-specific symptoms such as depression and sleep disturbances. Finally, animal studies suggest that physical activity could slow disease progression. Simply informing people about the importance of physical activity seems insufficient to initiate and maintain an adequate activity level. The ParkFit study is designed to evaluate a PD-specific physical activity promotion program (the ParkFit program) that aims to increase the level of daily physical activity over a two year period in sedentary patients with PD.

Methods: Specific elements of the ParkFit program include: a personal activity coach; an ambulatory activity monitor with visual feedback of daily activities; an educational activity workbook; and a personal Health Contract. The merits of this program will be evaluated in a multicentre, randomised controlled trial, scheduled to include 700 sedentary PD patients, randomly assigned to either "usual physiotherapy" or to the ParkFit program. Primary outcome measure is time spent on physical activities per week, measured by 7-day recall. Secondary outcome measures are: (1) physical fitness; (2) quality of life; and (3) level of physical activity in kilocalories per week. We also document the risks of improved physical activity. Assessments take place at baseline, and after 6, 12, 18 and 24 months.

Conclusions: The study will clarify whether a PD-specific physical promotion program will result in a meaningful improvement in physical activity levels over a two year period. Furthermore, we will search for possible disease-specific health benefits and risks of improved physical activity, as well as possible (individual) predictors for successful implementation of the program. Baseline assessments have been started in September 2008 and are continued to September 2009. At the ISPGR congress, preliminary results can possibly be presented.

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Markerless approach for the characterization of the standing reach

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Introduction: The objective of this work was to derive a procedure able to estimate joint kinematics relative to a simple, yet functionally relevant, motor task using a markerless approach. Standing reach (SR) [1,2] is the motor task analysed. The motion is mainly confined to the vertical plane. It consists in leaning the trunk forward trying to reach the maximum displacement of the arms, and maintaining the wrists at approximately the same height during the whole movement. The base of support is fixed during the task because the subjects are required not to lift their heels or step forward. The maximum displacement of the hand is a measure of clinical significance for its predictive value about recurrent falls in the elderly subjects. Nevertheless this measure, *per se*, cannot be considered a measure of dynamic balance, in the sense that is not able to differentiate healthy elders from individuals with balance impairments. More insight can be obtained from the same motor task if it can be described, in an objective way, looking at its kinematic behaviour [2,3].

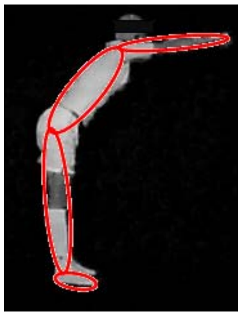

Fig. 1a Approximation

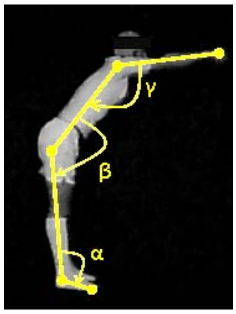

Fig. 1b Joint angles

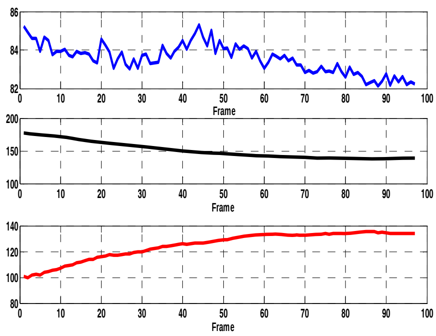

Fig.2 Angular trajectories (deg)

Methods: A single webcam (resolution: 352x288 pixels) was placed orthogonally to the subject and calibrated using the Zangh's method [4]. The frames were converted to grayscale, and segmented by an automatic thresholding technique. The subject was modeled as a kinematic chain of 4 segments: foot, leg, trunk, and arm. The body segments have been approximated by ellipses (Fig.1a) using a Discrete Curve Evolution algorithm [5] and tracked among frames making reference to an area constraint. The angles between adjacent segments (Fig.1b) were calculated using the automatic identification of the major axis of ellipses associated to the relative body segments. The maximum displacement of the hand was determined as Euclidean distance between the end (last frame) and the initial (first frame) position of the distal vertex of the ellipse associated with the arm.

RESULTS: Figure 2 shows the angular trajectories related to one young and healthy subject. The maximum displacement of the hand was 0.27 m. The computation time required for the automatic analysis of each frame was 1.8 seconds.

CONCLUSIONS: These results are similar to those found in literature [1,2,6] but are here obtained with a low cost and easy to use technique. Future step is to remove some acquisition constraints that have allowed to reduce shadow problems.

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Assessment of ascending and descending stairs: how many stairs are required?

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INTRODUCTION: The Time Up and Down Stairs Test (TUDS) has been suggested as a measure of functional mobility [1]. This test requires subjects to walk quickly but safely up and down a 14-step flight of stairs. Time was started when given the cue to go and stopped when the second foot returned to the floor. In order to allow for differing numbers of stairs and to separately determine ascent and descent times a method of measuring time per stair was devised. This study looks at how many stairs are needed to obtain repeatable measurements.

METHODS: The sample consisted of 35 healthy young adult subjects, 23 females and 12 males, with mean age of 23.4. The stairs had a tread of 28cm and a rise of 17.5 ± 1.5cm. The number of stairs used was 4 – 8 with the sequence randomized. The subject stood with toes on a line drawn 10cm from the front edge of the first stair and asked to walk up the stairs as they would at home. A multimemory stopwatch was started when the subject was cued to start and the lap/split button was clicked on each contact with a stair and stopped when the second foot touched the top stair on ascent or the floor on descent. The first step and last step were ignored and the mean time per stair was then calculated. Data were analyzed using a repeated measures ANOVA with a Tukey post hoc test to determine differences.

RESULTS: When considering the number of stairs ascended or descended there were no significant differences found in the mean time per stair measurements. When all the stair ascent data were pooled and compared to all the stair descent data a statistical difference was revealed using a Student t Test for paired data ($p < 0.0001$). The mean time per stair for ascent was 0.51s (SD 0.006) and for descent it was 0.47s (SD 0.006).

CONCLUSIONS: Time per stair is a useful measure of functional mobility that allows for comparison with performance during stair ascent and descent. It also allows for comparison of data collected using different numbers of stairs. From a clinical perspective the study also suggests that a four-stair module, commonly used rehabilitation facilities, could be used for assessment purposes, provided the stairs have the appropriate tread and rise dimensions.

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Balance responses to lateral perturbations in treadmill walking

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INTRODUCTION: Model studies predict that lateral balance is maintained by a stepping strategy [1, 2]. To verify this prediction, experiments with lateral perturbations have been done.

METHODS: During walking on a treadmill ten human subjects (mean age 20 yr.) were perturbed by 100 ms pushes or pulls at waist level, to the left or the right, of various magnitude and in various phases of the gait cycle. The centre of pressure was recorded by force transducers on the treadmill. Positions of the centre of mass and extrapolated centre of mass were calculated from the centre of pressure based on the inverted pendulum model [3]. EMG recordings were made from seven muscles bilaterally.

RESULTS AND CONCLUSIONS: Balance was mainly maintained by a stepping strategy, in which the foot at the next step is positioned a fixed distance outward of the ‘extrapolated centre of mass’ [2]. Additionally a lateral ankle strategy was used. The ankle strategy is the fastest, with a mechanical delay of about 170 ms, but it can displace the centre of pressure no more than 2 cm. It is executed by medium latency reflexes of mm tibialis and peroneus. The stepping strategy needs at least 300 ms before foot placement, but has a much greater range. Muscle actions of mm gluteus medius and adductor magnus were related to this strategy. Balance could be recovered within one stride. Other strategies, the trunk strategy and swinging the arms, come to the rescue only at greater perturbations, those which increase lateral velocity of the centre of mass more than about 0.2 $m.s^{-1}$.

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The effect of turns on walking speed during the 6 minute walk test

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INTRODUCTION: The 6 minute walk test (6MWT) is a useful measure of endurance in the rehabilitation setting. The test is commonly administered on a track, but for clinical use it is more convenient to have patients walk back and forth along a corridor [1-2]. The American Thoracic Society recommends a distance of 30m, however available space may be limited requiring shorter distances to be used. The shorter the track distance the greater the number of turns that must be made, which may result in a shorter distance walked in 6 minutes. This study looked at the effects of track length on walking speed and distance during a 6 minute walk test.

METHODS: The track was set up in a corridor. Tape was used to draw arrows at the ends of the track and a line at the midpoint of the track as shown in Fig. 1 Track lengths (D) of 10, 20 and 30m were used. The sample consisted of 68 young healthy adults (21 males and 47 females) with a mean age of 23.5. The 6 minute walk was performed for 10, 20 and 30m in a randomized sequence. For each track length, subjects started walking at the midpoint line and were instructed to walk back and forth along the track as many times as they could in six minutes. They were required to cross the lines at each end and to turn in the direction of the arrows. A multimemory stopwatch was started when the subject was given the cue to walk. Each time the subject passed the midpoint the lap button was clicked and the lap and split times recorded. After 6 minutes of walking the stopwatch was stopped when the subject next passed the central point. For each test, the mean distance walked, lap time and walking speed were calculated. Data were analyzed using repeated measures ANOVA with a Tukey post hoc test to determine differences between track distances.

RESULTS: The means and standard deviations are shown for lap times, walking speed and distance walked for the three lap lengths. Analysis revealed that the values for each measure were statistically different ($p < 0.001$) for each of the lap lengths.

CONCLUSIONS: This study shows that lap lengths shorter than the 30m recommended by the ATS will result in reduced walking speed and distance walked in 6 minutes.

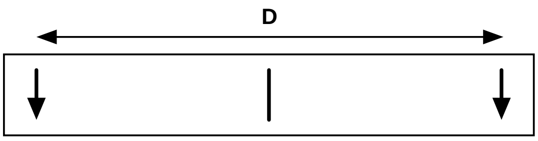

Fig.1 Plan view of walkway. Arrows at the ends of the walkway indicate turn direction

	10 meters	20 meters	30 meters
Mean Lap Time (s)	7.10 (± 0.88)	12.88 (± 1.72)	17.18 (± 2.31)
Mean Speed (m/s)	1.43 (± 0.18)	1.58 (± 0.21)	1.74 (± 2.31)
Mean Distance (m)	514.85 (± 64.52)	568.79 (± 76.79)	625.70 (± 76.25)

Table 1. Means and standard deviations for lap time, speed and distance for each lap length

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Development, content validation and reliability of a clinical instrument to identify biomechanical characteristics and strategies adopted by subjects with hemiparesis following stroke during the Timed “Up and Go” test: Establishment of the first version

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INTRODUCTION: Although all of the advantages that have been established for the Timed "Up and Go" (TUG) test to assess functional mobility of stroke subjects [1], the only provided outcome is the time spent to perform the task. There are well established changes of some biomechanical characteristics and strategies adopted by subjects with hemiparesis due to stroke during the performance of important activities related to basic mobility, as evaluated by the TUG test [1]. It is thus, necessary to develop a reliable and valid measure which allows the systematic evaluation of these changes and strategies. Therefore, the aim of this study was to develop a clinical instrument to identify the biomechanical characteristics and strategies adopted by hemiparetic subjects during the performance of the TUG test and to investigate the content validity and reliability of the developed instrument to establish the preliminary version.

METHODS: The study was developed in three phases following the steps described by Benson and Clark [2] and Davis [3]. In the first phase, the previous version of the instrument was elaborated considering the extensive and systematic analyses of three different sources of information: The literature, the opinion of 14 rehabilitation professionals, and the exhaustive observations of the videotaped performance in the TUG test by 22 hemiparetic subjects and 22 healthy subjects. During the second phase, the content validity of the instrument was investigated by an expert panel that was composed of well-known professionals involved in motor and functional rehabilitation of stroke subjects with significant publications in refereed journals and conference proceedings. In the third phase, the intra- and inter-rater reliability was investigated by two independent examiners who twice evaluated the TUG performance of 12 stroke subjects four weeks apart.

RESULTS: The first phase resulted in a 24 item instrument and each item had three response categories. Based upon the recommendations of Benson and Clark [1] and Davis [2], the number of items developed for the preliminary version of an instrument should exceed the desired final instrument length by 1.5 to 2.0 times. Creating excessive items should assure a sufficient number of items in the pool after testing. Therefore, this previous version of the instrument had 24 items: five related to the sit-to-stand, task, eight to gait, five to turning, and six to the stand-to-sit task. The second phase resulted in a 21 item instrument with adequate content validity. According to the modified Kappa statistics, the levels of agreement between the expert panel members ranged from 0.72 to 1.00 for those 21 items. In the third phase, out of the 21 items, 19 showed significant intra- and inter-rater reliability (Kappa of $0.36 \leq k \leq 1.00$; $p \leq 0.04$).

CONCLUSIONS: After all these phases, the first version of the instrument was established with the 19 items with adequate content validity and reliability: Four related to the sit-to-stand task, seven to gait, four to the turning and four to the stand-to-sit task. In conclusion, the first version of the instrument appeared to be a reliable and valid measurement of the evaluation of the biomechanical characteristics and strategies of subjects with hemiparesis during the TUG test. However, before its use in clinical and research settings, it is necessary to establish its criterion and construct validity.

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Can an accelerometer enhance Timed-Up & Go test sensitivity among patients with Parkinson's disease?

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INTRODUCTION: The Timed Up and Go (TU&G) is a widely used measure of mobility and fall risk in older adults and in patients with Parkinson's disease (PD). Performance on the TU&G is typically quantified by measuring the time required to complete the test (i.e., stand from a seated position, walk 3 meters, turn around, return to the chair). In this study, we tested the hypothesis that insight into gait and mobility among patients with PD could be further achieved if subjects wore a small, lightweight body-fixed sensor, i.e., an accelerometer, as they carried out the TU&G.

METHODS: We examined 18 patients with PD (Hoehn and Yahr range: 2-4; mean age: 65.6±5.0.yrs) and 15 age-matched healthy controls (CO). Subjects wore the Mobi8 system (TMSI International) which included a 3-D accelerometer that was worn on the lower back. The sit-to-stand and stand-to-sit components of the 2nd of two trials were analyzed. Measures included the sit-to-stand, stand-to-sit range of the anterior-posterior (AP) accelerations (Rap_start, Rap_end, respectively), and the minimum, maximum, median, standard deviation, coefficient of variation and main harmonic of acceleration in all 3 axes. These measures were also extracted for derived signals such as the moving average and dynamic range of acceleration calculated over 0.25, 0.5, and 1.0 second windows. We also evaluated the high and low frequency content of the signal (low band= 0.5-3 Hz, high band=3-8 Hz) and their ratio.

RESULTS: As anticipated, the TU&G duration tended to be higher for the PD group compared to the CO group (9.88±2.71 seconds, 8.73 ±2.00 seconds, respectively), although the difference was not statistically significant ($p>0.1$). The low AP frequency power in the locomotion band (0.5-3 Hz) was significantly lower ($p<0.007$) in the PD versus CO group (4.5±2.5 1000*power/rad/sample, 6.7±1.9 1000*power/rad/sample, respectively). Rap_start was significantly lower ($p<0.02$) in the PD group, compared to CO group (0.9 ± 0.3g vs 1.4 ± 0.6g, respectively). In contrast, Rap_end was not significantly different in the two groups. The median AP acceleration value was significantly higher ($p<0.01$) for the PD compared to the CO group (0.2±0.2g vs. 0.0±0.2g respectively). This may be due to a higher trunk tilt in the patients which increases the amount of static vertical gravity component that is present in the AP acceleration. The median accelerations in the other two dimensions were not significantly different between groups.

CONCLUSIONS: Although there was no significant difference between patients with PD and age-matched controls when examining the traditional TU&G duration, accelerometer-derived measures were more sensitive to group differences, especially the decreased activity in the locomotion band and the decreased range of motion in the sit-to-stand AP portion of the TU&G. These findings indicate that patients with PD have a lower starting momentum when rising from a chair. The higher AP acceleration values for PD may indicate that PD subjects tend to have a higher trunk tilt (i.e., stooped posture) while performing this task. Together, these results demonstrate the potential of using an accelerometer that measures TU&G activity to detect and quantify subtle differences in mobility and function. Perhaps, such measures will be able to improve our ability to identify early markers of PD and to document disease progression and the response to therapeutic interventions.

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Postural stability of walking subjects in response to lateral perturbations

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INTRODUCTION: Postural stability in the lateral plane is reduced during walking because the base of support is reduced, especially during the single support phase of the gait cycle. Consequently, frail elderly people tend to fall sideways during locomotion [1]. Postural stability in the lateral plane is further threatened by lateral perturbations when walking in some forms of transport (e.g. passengers walking in trains). This laboratory study was designed to identify the lateral perturbations of vehicles that disrupt the postural stability of walking passengers. The frequencies and magnitudes of low frequency fore-and-aft and lateral oscillation that cause instability in stationary standing subjects have been investigated previously [2], but there have been few studies of the effects of low frequency oscillations on the dynamic stability of walking persons.

METHODS: The study involved twelve young healthy male subjects (aged 25 to 45 years) with no known balance problems. Subjects walked on a treadmill containing force plates (Kistler Gaitway®) secured to a motion simulator capable of six-axes of motion. The treadmill was perturbed by all combinations of seven magnitudes (0.2 to 1.0 ms^{-2} r.m.s.) and eight frequencies (0.5 Hz to 2 Hz) of transient lateral oscillation (Figure 1). For safety, subjects were attached by a loose safety harness that prevented falling. They walked without holding handrails unless they felt unsafe. After each stimulus, the subject and the experimenter independently judged the postural stability of the subject on a subjective scale. Postural stability was also assessed by the force sensors in the treadmill.

RESULTS: The results show how the self-rated postural stability of the subjects depended on the magnitude and the frequency of the lateral motion of the treadmill and will be presented at the conference. The findings are being used to determine thresholds for the motions that result in loss of balance in walking persons.

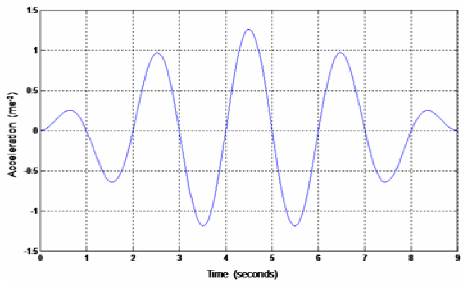

Fig.1 Form of transient oscillations

CONCLUSIONS: The experiment was designed to contribute to a basic understanding of how lateral oscillation of a floor perturbs the postural stability of walking subjects. Stability thresholds determined in the study will be used to develop a model of postural stability in the lateral plane during locomotion. The dependence of postural stability on the frequency and magnitude of motion can be used to evaluate and assess vehicle ride comfort where walking is required during transport.

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Analysis for Stepping by Force Platform and Motion Analysis System

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INTRODUCTION: The increase of the variability of ground reaction force possibly suggests the severity of gait instability (1). An analysis of walking is quite complex, however it has been thought that a stepping motion resembles normal gait in some ways, and an analysis of stepping pattern is more simple (2). We therefore investigated the dynamic motion and the ground reaction forces to understand the limb dynamics during stepping.

METHODS: Ground reaction forces under each foot during stepping were recorded separately at a sampling rate of 100Hz with two force platforms spaced by 1cm between each other (Anima G-620, Japan) in 20 healthy subjects. They were asked to step as feeling a small circular cylindrical mark on the force platform with their sole of their feet. Simultaneously the motions of passive infrared reflective markers on the selected points of the body were analyzed to evaluate the bilateral kinematics of lower limbs during stepping by using motion analysis system (Anima MA-200, Japan). In order to investigate whether a difference of the cadence influences stepping parameters (the variability of ground reaction force under each foot in stance phase, coefficient of variance of stance phase duration, toe clearance (vertical distance between the toe marker in swing phase and the force platform)), we asked subjects to step for 20 seconds at 4 different cadences (60 steps/20s, 35 steps/20s, 20 steps/20s and comfortable cadence) at random orders. They underwent the stepping test with eyes open and eyes closed.

RESULTS: The coefficient of variance of stance phase duration and variability of ground reaction force under each foot in stance phase during stepping with eyes closed at comfortable cadence was significantly greater than with eyes open ($p<0.01$). The variability of ground reaction force under each foot in stance phase at the cadence of 60 steps/20s (left 6.35, right 5.78) was significantly higher than that of 35 steps/20s (left 4.83 $p<0.01$, right 4.64, $p<0.01$). In addition, the average of the toe clearance at the cadence of 60 steps/20s (left 9.9cm, right 9.2cm) was smallest in comparison to other cadences.

CONCLUSION: Our results suggest that very rapid stepping increases variability of ground reaction force and reduces the toe clearance, resulting in reducing dynamic postural stability while stepping and increasing the occurrence of stumble and fall.

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Experimental study on interactions between walkers having crossing trajectories. Part I. Experimental setup, interaction starting and solving

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INTRODUCTION: Until now, moving obstacle avoidance in human walking has been studied through protocols using a mannequin mounted on a rail [1, 2]. The following protocol (Fig. 1 - *left*) was designed to study interactions between two real walkers. In this first part, we ask two main questions. What are the conditions for participants to adapt their trajectory, i.e., conditions for an interaction to occur? Is an interaction solved in a collaborative manner or by one participant only?

METHODS: 30 subjects divided in five groups of six volunteered to the study. The six participants stay still at the corner of a square experimental area (15m. long). Two of them receive a start signal (one along each diagonal) and were asked to reach the opposite corner at comfort speed, with no other indication. During the first initial phase, they are not able to observe each-other due to the presence of occluding walls, not knowing from which side and even if someone would actually come. The second phase, interaction, starts when participants have reached comfort speed and are able to see each other. They are then likely to adapt their trajectory to avoid each other. Interaction study arbitrarily ends when the minimum distance between walkers is reached. We recorded participants' trajectories (452 experimental samples) using an optical motion capture system. The *predicted minimum distance* (*pmd*) is defined as the minimum distance at which participants would meet if they continue walking with same instantaneous direction and speed. *Pmd* can be computed at any time in experimental data. Each subject adaptation is quantified through his acceleration norm, both taking speed and orientation changes into account.

RESULTS: Participants adapt their trajectory if, and only if, the *pmd* value was below 0.9m. The plot in Fig1. – *right* illustrates the mean acceleration over all experiments (colour-scale), function of time remaining before collision (horizontal axis) and *pmd* value (vertical axis). The lower the *pmd* is, the later the reaction and the higher the acceleration is to adapt the trajectory. Moreover reaction comes after an *observation period* whose duration changes inter-experiment. Interactions are solved in a collaborative manner most of the time, especially when interaction is strong (for low *pmd* values). However, the role of participants is not symmetrical, as, on average, the first participant passing at trajectory crossing is making much less adaptations than the participant giving way.

CONCLUSIONS: *pmd* is a pertinent criterion to study interactions: the presence of trajectory adaptations, as well as their magnitude, can be directly related to *pmd*.

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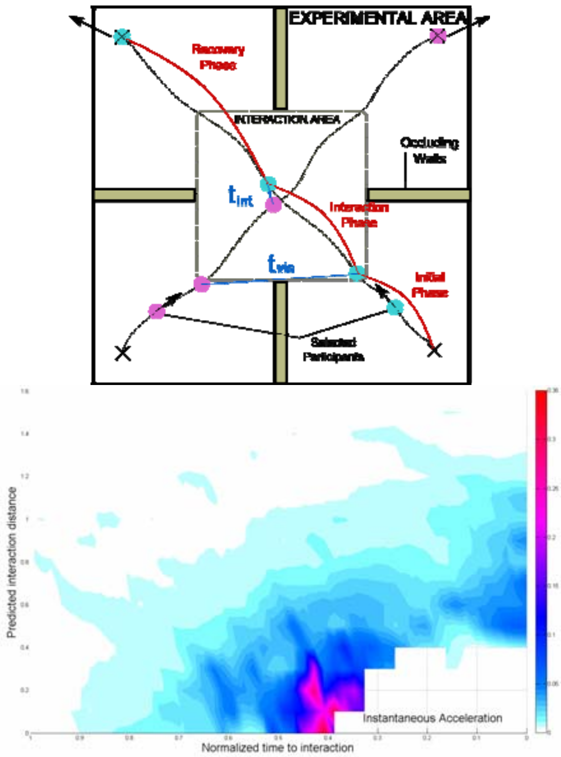

Fig1. (Upper) illustration of the experimental protocol. (*Lower*) mean acceleration over all experiments function of time to collision and predicted minimum distance at crossing

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Experimental study on interactions between walkers having crossing trajectories. Part II. A leader-follower interaction

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INTRODUCTION: Previous studies on moving obstacle avoidance have provided interesting results about the strategies used [1, 2]. However, they did not consider the complex interaction between two walkers. To avoid collision each walker can have a speed strategy, passing before or after the other one, or an orientation one, passing in front of or behind the other one. The first part of this study showed that the behaviour of the two walkers were different, the one passing first doing less [3]. The aim of this second part is to investigate the strategy used by each subject.

METHODS: 30 healthy subjects volunteered to the study. Within each trial two subjects were asked to walk between two 20m distant points with no other indication. The experimental procedure implied 90° crossing trajectories (for details see part I [3]). The *predicted minimum distance* (*pmd*) is the minimal distance at which participants would meet if they continue walking without adaptation. The first *pmd* (*fpmd*) is the one computed when they first see each other. Subjects' trajectories were approximated step by step by an arc of a circle, computing mean curvature and speed between two heel strikes (see Fig 1). Speed and orientation adaptations were computed comparing one step with the previous one. Global adaptations were set as their cumulated sum. An adaptation was considered efficient if it raised the *pmd*, inefficient otherwise. For each value of *fpmd*, we computed the percentage of efficient speed and orientation adaptations for each subject: the one passing first (S1) and the other one giving way (S2). A preference threshold based on probability computation using binomial distribution allowed to assess whether the strategy choice was deliberate or at random.

RESULTS: The kind of strategy used is not the same for the two subjects. S1 mainly used speed adaptation whereas S2 used orientation adaptation. Orientation strategy (resp. speed) preference is detailed on Fig 2.a (resp. Fig 2.b); the preference threshold is represented by the horizontal lines. Moreover, the decision to actually add an avoidance task to the navigation task is subject dependant. When the collision risk is high (*fpmd*<.45m), both subjects actually try to avoid each other. When the collision risk is low (*fpmd*>.9m), no subject modify his speed or orientation. When the collision risk is medium, between these two *fpmd* values, only S2 complete the avoidance task.

Conclusions: Collision avoidance strategy between two walkers is solved through a leader-follower interaction. This could be linked to the asymmetry of the personal space ellipse which is larger in the frontal direction than in the lateral one. Indeed, when crossing each other S1 is in front of S2 whereas S2 is beside S1.

Acknowledgements: This study was funded by ANR-Locanthrope project

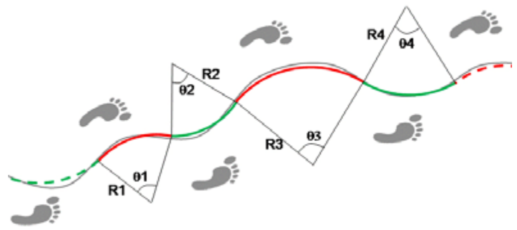

Fig.1 Modeling of trajectory

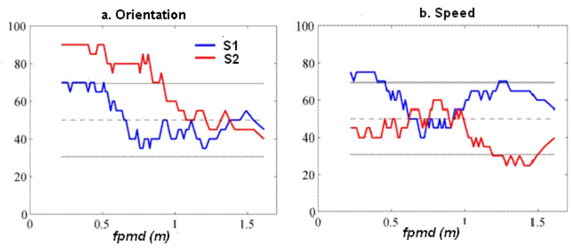

Fig. 2 Percentage of efficient orientation (a) and speed (b) strategy trials with respect to *fpmd*.

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Trunk control testing using a stationary target paradigm

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Introduction: Paradigms that examine trunk neuromuscular control are crucial not only for identifying the role of poor trunk control in patients with non-specific low back pain, but also in determining the efficacy of trunk motor control interventions widely used in clinical practice. We developed an 8-direction radial-target acquisition task to evaluate isolated trunk motor control performance. The purpose of this study was to evaluate our protocol for testing dynamic trunk control using volitional control of seated balance and trunk movement on an unstable surface.

Methods: Trunk control of 10 individuals (7 healthy, 3 low back pain) were tested on 2 occasions using our seated paradigm. The testing apparatus was designed to isolate trunk control by minimizing the contribution of the lower extremities. Subjects sat on a seat with a 44 cm diameter hemisphere mounted underneath and an adjustable foot rest allowing positioning of the subjects at 90 degrees of hip and knee flexion. The seat created an unstable surface there by requiring active trunk control to maintain an upright seated posture [1]. The seat was placed on a force plate at the edge of a raised platform. We first tested the participants limits of stability (LOS) by having them actively tilt the chair moving their center of pressure (CP) along radii positioned at 8 different angles (0º, 45º, 90º, 135º, 180º, 225º, 270º, 315º) from a center target (average static balance position). The subjects received visual feedback on their CP position during the tests with the goal of tilting the chair as far as they could along the radius without losing their balance. The test was completed with the subjects arms crossed over their chest. Dynamic trunk control was tested using a center-out protocol where the distance of each target from the center target was set at 90% of the subject's LOS. Each test began with the subject establishing balance control. At the start of the test, 8 circle targets of an equal size became visible on the computer. The first of 8 targets was highlighted and the participant was instructed to tilt the chair toward the target as quickly and accurately as possible. After activating a radial target, the center target was highlighted and the participant moved back to center position. At that point that the next radial target was activated. Targets were always presented in the same order. Three training and 6 test trials were performed. Force data were collected at 1600 Hz, filtered at 16 Hz and CP time series calculated. We examined task performance using CP excursion (LOS), deviation from a standard path (directional control), and mean velocity [2]. Test-retest reliability of these parameters was determined using ICC (3, k).

Results: The performance parameters demonstrated poor to good reliability between test sessions. $ICC_{(3,2)}$ values ranged from .48 to .83 for the LOS over the 8 different target directions. The reliability of the mean velocity in each target direction $ICC_{(3,6)}$ ranged from .07 to .81. Directional control values ranged from .39 to .88 $ICC_{(3,6)}$.

Conclusions: Our results suggest that this novel task may require more practice trials prior to stabilization of the measurement. This suggests there may be a learning effect of this challenging and unfamiliar task. While subjects demonstrated more consistent LOS, their ability to performance consistently in all directions of the target test may require practice, reduced target distances (< 90% LOS) or more specific subject instruction.

ACKNOWLEDGEMENTS: Supported in part by grants from NIH NICHD K01 HD053632 and NIH NINDS R01 NS44564, NS54894.

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No more movement, not yet posture: a method for the analysis of stabilisation following a movement

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INTRODUCTION: While erect posture and the response to external perturbations have been widely studied, comparatively few studies have addressed how posture is pursued and controlled after a movement [1,2], assuming the preliminary movement as an internal perturbation. We hypothesize the occurrence of a transition phase between the macroscopic movement and the final steady posture, with a stabilising goal. Our objective is to define a method to identify and characterise the stabilisation phase and to provide normative data of related quantitative indexes.

METHODS: The experimental setup consists of a dynamometric platform. The protocol includes quiet erect posture preceded by a single forward step or by standing up. In those tasks, the forward component of ground reaction (AP) show a constant negative value when approaching the platform, then the value oscillates around zero accounting for postural accommodations about a point of equilibrium. It is quite common to observe a progressive decrease of the oscillation amplitude until a steady oscillating pattern is reached. The time of end of movement and beginning of the oscillation transitory (t0) is identified as the first null jerk occurrence. An accessory variable, quantifying the instant rate of instability, is computed as the RMS of the reaction AP component in the 1-second window following the current instant. A compound instability AP RMS variable is then composed by the median values of the synchronized AP RMS profiles of three repetitions. Finally, a negative exponential profile (Y = Yinf + (Y0-Yinf) *exp(-t/T)) is fitted onto the AP RMS data (Fig.1), only if the AP RMS value at t0 is larger than the final average value. The identified parameter T is proportional to the decay of the instability from initial larger values to the smaller values of the steady posture, and Y0 is the initial rate of instability. Forty normal subjects (age range from 11 to 80) participated to the study.

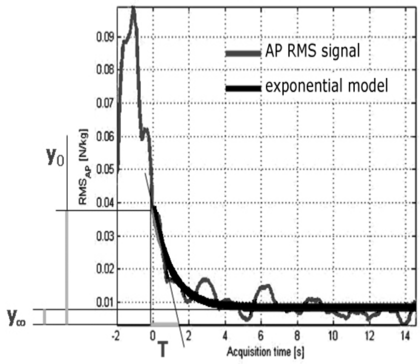

Fig.1

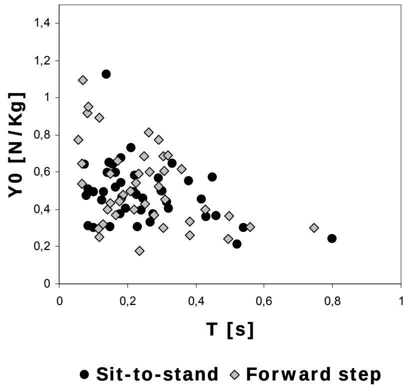

Fig.2

RESULTS: The experimental data always matched the method requirements and the model successfully fitted them. The scatter-plot (Fig.2) reports all the coupled Y0-T outcomes, accounting for a certain variability. Apparently, it is observed no strict relation between Y0 and T but, at the same time, coupled large values of Y0 and T were not observed in any subject. Our interpretation is that a lower rate of initial instability is passively managed and evolves in longer time, while an initial larger instability requires a quick, possibly active, response and therefore a faster stabilisation. Moreover, computed Yinf were smaller than Y0 and independent from the motor task.

CONCLUSIONS: The normative data proved that the hypotheses of the study were correct and that the proposed method is able to evidence the stabilisation phase. Future studies will assess the sensitivity of the stabilisation phase to motor disorders.

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Reduced modular control accounts for muscle activation during walking in persons with incomplete spinal cord injury

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INTRODUCTION: Motor commands for walking control may be organized within a modular framework [1]. This framework associates a single neural command with synergistic muscle activity to coordinate biomechanical sub-tasks during walking [2,3]. Four to 5 modules may coordinate control of walking in healthy individuals. Recent work in our laboratory indicates fewer modules are required to explain muscle activation in the paretic leg of persons post stroke. Fewer modules were associated with poorer walking performance and resulted from abnormal co-activation and the inability to differentially activate discrete muscle synergies [4]. The purpose of this study was to extend this work and examine modular control used by persons with incomplete spinal cord injury (ISCI) and to characterize their motor function and locomotor performance.

METHODS: Seven persons with ISCI (5 males, 43.5 ± 22.5 years) walked on an instrumented split belt treadmill and over-ground at a self-selected speed. Non-negative matrix factorization was applied to rectified and filtered EMG recorded in eight bilateral lower extremity (LE) muscles during treadmill walking. Two to five factors were used to reconstruct the EMG to determine the minimum number of modules required to explain ≥ 90% of the variability in the recorded EMG. The composition and weighting of muscle activity was examined relative to the timing of key biomechanical subtasks. The American Spinal Injury Association lower extremity motor score (LEMS) was used to examine motor function. Use of assistive devices and level of assistance were assessed using the Walking Index for Spinal Cord Injury (WISCI).

RESULTS: Individuals with ISCI walked over-ground at 0.18m/s to 0.80m/s. All had a LEMS ≥ 40/50, yet WISCI scores ranged from 8 to 17/20. The pattern of LE EMG during treadmill walking was explained by an average of 2.8 modules (mode=2). Across the 14 LEs, two (43%) or three (36%) modules adequately reconstructed the EMG. Of the LEs using two modules, the first module was active during the first period of double support and consisted of co-activation of the soleus, vastus medialis, medial gastrocnemius, lateral hamstrings, and gluteus medius muscles. The second module, dominated by activity in the tibialis anterior and rectus femoris muscles, was active during swing. Three LEs used four modules, demonstrating activation similar to healthy individuals. Two individuals that used power wheelchairs for community mobility had the most compromised modular control, activating two modules, bilaterally.

CONCLUSIONS: Persons with ISCI rely on fewer modules to coordinate muscle activation during walking. This suggests that differential control of muscle synergies used to control biomechanical subtasks is compromised after ISCI. Examination of modular control provides a framework for assessing the relationship between neural commands, muscle activation, and the biomechanical requirements of walking. These methods may also be useful for assessing the effect of rehabilitation on walking control.

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Distinguishing among different lower limb physical activities through a Bayes' classifier applied on features extracted from single-axis accelerometer data

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INTRODUCTION: The use of accelerometers to reveal and classify activities of daily life is at present a popular research topic. The interest is now shifting on providing algorithmic solutions able to minimize the set-up and let the subjects perform activities in an almost unconstrained scenario, at the same time providing accurate results in terms of classification performance. In this context, the objective of the present work is to recognise walking, stair descending and stair climbing in a natural scenario with a minimally intrusive setup.

METHODS: Five young adults were instructed to follow an indoor and outdoor pathway consisting of phases of different ramp and level walking, stair descending and stair ascending, and lasting around 15 minutes. They wore a belt containing a PDA connected to a single axis accelerometer placed on the shin. For each subject, after the detection of individual epochs, 16 features were extracted from the time and frequency domain trajectories. To reduce the dimensionality of the dataset and determine if the different activities (i.e. walking, stair descending and stair climbing) could be effectively distinguished, 2D Sammon's mapping was performed on a 20% of the detected epochs, and an Artificial Neural Network (1 hidden layer, 40 neurons) was designed and trained to estimate the Sammon's mapping function. The remainder of the detected epochs was then used to test the system consisting of the ANN and the Bayes' classifier. This latter one was set up by considering the conditioned probability densities as estimated by the ANN outputs of the training set, and the *a priori* probabilities as estimated by the frequencies of occurrence for each of the three activities in the training set. The maximum *a posteriori* estimation was then used as decision criterion.

RESULTS: A cumulative number of 1467 activities was detected and underwent the classification. Out of them, an average of more than 91% of activities was correctly classified. Errors were, on the vast majority, coming from ramp walking ascending steps performed by one of the subjects, which were misclassified as stair climbing steps.

CONCLUSIONS: Through a single-axis accelerometer it is possible to reliably distinguish among the lower limb activities monitored in this study. The mapping function helped in setting up a 2D Bayes' classifier based on just one accelerometer sensor, with no substantial loss of performance in classification as compared to most classifiers used in this context. The encouraging results are in line with the hypothesis of using minimally intrusive devices to remotely monitor, and distinguish among, different physical activities performed in field settings.

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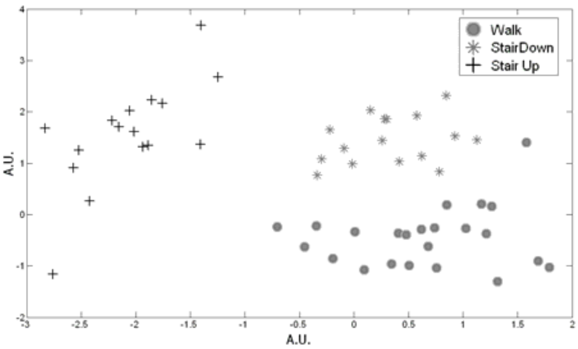

Fig.1 Sammon's map output for one selected subject (training set)

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Validity of an Optical Proximity Sensor (OPS) to measure foot clearance during gait

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INTRODUCTION: A limitation in foot clearance studies has been the use of cameras to capture data. Such systems demand a laboratory setting and require the participants to walk in discrete bursts through the calibration volume resulting in a series of snapshots rather than a continuous collection of data over the many cycles that constitute steady state gait. The use of a treadmill may allow data to be captured from multiple steps but poses problems of generalisability into the more normal function of over ground gait. The development of an optical proximity sensor (OPS) gives rise to the potential to collect data over long periods and in natural settings. The aim of this study was to examine the concurrent validity of an OPS through comparison with a 3D Motion capture system in measuring foot clearance.

METHODS: Fifteen subjects aged 33.1 (sd 10) years, height 174 (sd 6.4) cm and weight 75 (sd 12.2) kg walked at three velocities (preferred, preferred slow and preferred fast), repeating each velocity 3 times. An OPS that produces a voltage directly proportional to the distance from the sensor to the nearest object was placed on the shoe of each subject so that the OPS could measure height above the ground at approximately the head of the 5th metatarsal, offset by the shoe and sensor height. A reflective marker was placed on the outer casing of the OPS. The marker was tracked with a seven camera motion analysis system (Qualysis) at 50Hz. Motion capture and the OPS were synchronised at the start of every data collection. The lowest point during the swing phase (Figure 1) was recorded from each system and these data compared using ICCs and levels of agreement.

RESULTS: There was excellent agreement between the two systems. ICCs of 0.925 (all speeds), 0.931 (PWS), 0.966 (PWS slow) and 0.889 (PWS fast) were recorded. Overall there was agreement to within 4.5mm (5.5% of measurement range) over 135 samples.

CONCLUSIONS: Because of differences in measuring techniques the shape of the curves differ; especially during initial swing (Figure 1) however these results represent a strong agreement between the two systems in measuring the lowest point during swing. The OPS could thus be used instead of cameras to record foot clearance. This opens up opportunities for future research to record foot clearance over long periods of time and in natural settings. These results should be seen in context of the young healthy sample. In this group the posture of the foot at mid swing was consistently parallel to the ground making calculation of foot height from an OPS unproblematic. This may not be the case for old and clinical populations. Planned modifications include a method of adjusting the calculation for inclined feet.

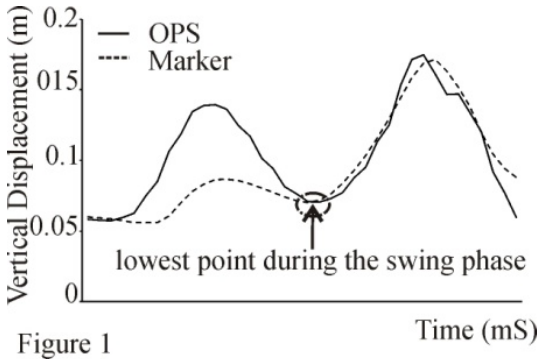

Figure 1

P.362

Is gait analysis possible using only an accelerometer?

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INTRODUCTION: Is gait analysis possible using only an accelerometer? This study aimed to analyze walking using a skin-mounted accelerometer, to investigate the relationship between walking and floor reaction force, and to determine the frequency characteristics of an applied acceleration wave pattern.

METHODS: The participants were 21 healthy young men (age, 20.0 ± 2.0 years; height, 170.3 ± 2.3 cm; weight, 63.0 ± 7.9 kg: mean ± standard deviation). A triaxial accelerometer was fixed to the subjects' skin above the left tibial medial malleolus. The subjects walked barefoot at their preferred speed (3.9 km/h, ± 5%) and at a constant speed on a floor reaction plate. The same protocol was repeated 3 times. Initial peak acceleration (vertical: A_v, progressional: A_p, lateral: A_l), initial peak floor reaction force (vertical: R_v, progressional: R_p, lateral: R_l), and peak-to-peak acceleration (vertical: PPA_v, progressional: PPA_p, lateral: PPA_l), were calculated. The mean value for each was adopted. The sampling frequency of the accelerometer and the floor reaction plate was 100 Hz. The correlation data were analyzed using Pearson's linear correlation coefficient. The gait cycle was also subjected to fast Fourier transform (FFT) analysis.

RESULTS: High linear correlations were found between A_v and R_v, and between A_p and R_p measurements during gait. A linear correlation was also found between PPA_l and R_l measurements during gait. The other parameters did not exhibit any correlation. The results of FFT analysis revealed that all subjects exhibited 2 peaks of 20 Hz or less.

CONCLUSIONS: The accelerometer was demonstrated to be clinically effective for gait analysis. A_v represents the quantity of vertical load. PPA_l represents the quantity of progressional perturbation. Human-beings cannot vibrate voluntarily by 20Hz or more. It has been reported that above-knee prosthesis gait acceleration peaks at 20 Hz or less and scatters at a higher frequency. The characteristic of the frequency seems to change depending on the appearance to walk. Therefore, the accelerometer can be used to examine gait and posture.

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Objective quantification of daily physical activity in children with Duchenne Muscular Dystrophy

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INTRODUCTION: Duchenne Muscular Dystrophy (DMD) is the most common muscular dystrophy in humans and affects 1 in 3500 males. DMD patients show progressive muscle degeneration and physical activity alteration with disease progression. Clinical scales such as the Motor Function Scale (MFM) [1] are used to evaluate motor function in patients and follow disease evolution. Although reliable, these scales can not quantify objectively the mobility or its absence during daily life. The aim of this study was to provide new metrics that can objectively assess the change of spontaneous daily activity of ambulant DMD children of different ages and disease severity.

METHODS: Daily life activity was monitored during three consecutive days, 10 hours each day, using a chest worn data logger (Physilog®) including a 3D inertial sensor (accelerometers and gyroscopes). Based on recorded signals, walking, standing, sitting and lying periods were assessed using a previous algorithm [2]. The following metrics were used to quantify the mobility: time percentage spent in walking, standing, on feet (standing + walking), sitting and lying, number of continuous walking episodes greater than 1, 2 and 6 minutes. Three groups of children were enrolled: control group (n=12, age=9.3±1.8), less severe DMD patients (MFM>87%, n=8, age=8.9±3.6) and more severe DMD patients (MFM < 87%, n=9, age=8.4±4.3). Non parametric test was used for the test significance at level of 0.05.

RESULTS: Table 1 compares the mean ± SD values of mobility metrics in the three groups. The time percentage spent on feet, in walking, the number of steps and the duration of the continuous walking episodes decreased with the severity of the disease, while the time percentage of the sitting and lying activity was increased. Most significant changes occurred between Control and more severe DMD patients. Less significant differences were observed in less sever DMD, probably due to small sample size.

CONCLUSIONS: In spite of the small number of subjects, the proposed metrics were evaluated on more than 850 hours of recording and were able to discriminate DMD patients with different level of disease severity. Future studies with more subjects are needed to validate these metrics and their reliability to quantify mobility in daily activities.

Metrics	Control	Slight DMD	Severe DMD
Time spent in walking (%)	20.9±5.5	15.8±4.2	10.9±4.1*
Time spent on feet (%)	54.7±6.9	48.2±5.9	43.6±10.1*
Number of steps	12522± 3581	8809± 2051*	6687±2970*
Time spent in sitting (%)	40.2±6.5	45.1±7.2	48.3±6.2*
Time spent in lying (%)	5.1±4.9	6.7±4.0	8.1±6.5
Number of walking episodes >1 min.	15.9±5.7	10.5±5.6*	5.3. ±2.7*+
Number of walking episodes >2 min.	3.6±2.1	2.2±1.4	1.0±1.2*
Number of walking episodes >6 min.	0.9±0.7	0.3±0.3	0*

Table 1 Mobility metrics. *: significant difference with Control, +: significant difference with slight DMD.

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Quantifying blind rehabilitation outcomes utilizing GPS and accelerometry

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INTRODUCTION: Historically, blind rehabilitation clinicians have relied upon subjective checklists and clinical assessments to document the capacity of individuals to perform various tasks, including mobility, and to assess changes in activity gained by attending Blind Rehabilitation. The continued development and implementation of outcomes instruments represents a major achievement in the coordination and standardization of measuring functional outcomes.

METHODS: This study highlights a unique, objective method for assessing mobility and activity in visually impaired individuals using a combination of GPS (Global Positioning Satellites), GIS (Geographic Information Systems), and accelerometer technologies. The use of these technologies facilitate a highly objective and reliable measurement of both indoor and outdoor mobility and travel patterns. The GPS/GIS and accelerometer data collected in this study was gathered as a mechanism to assess the reliability of self-reported travel behaviors of four research subjects. The purpose for this study was to test the methodology and procedures for future use in a large-scale research study. Consequently, the sample size was intentionally small (N = 4). The resultant GPS/GIS and accelerometer data accumulated in this study included: number of trips each participant made on each of the travel days, the level of activity on each travel day, the distance, maximum speed, and average speed per trip and documentation of each participant's activity space.

Statistics	Subject 1	Subject 2	Subject 3	Subject 4	TOTAL
Number of GPS trips	39	53	40	49	**45.3**
Number of days of travel	11	9	10	8	**9.5**
Average number of trips per day of travel	3.5	5.9	4	6.1	**4.8**
Weekday trips	21	40	26	27	**28.5**
Weekend trips	18	13	14	22	**16.8**
Weekday travel days	8	6	6	5	**6.3**
Weekend travel days	3	3	4	3	**3.3**
Weekday trip rate	2.6	6.7	4.3	5.4	**4.6**
Weekend trip rate	6.0	4.3	3.5	7.3	**5.2**

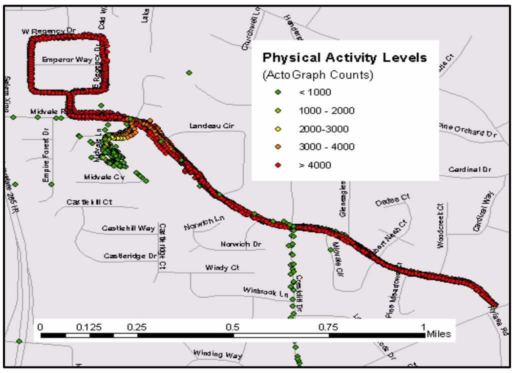

Table 1

The GPS second-by-second trace data, once received, was converted into GIS-compatible formats and then reviewed for potentially bad or poor data points. A program was subsequently run on the GPS data stream to identify potential trip ends based on time intervals between consecutively logged points. Additionally, when the activity data was downloaded, it was merged with the GPS data based on time and date. This allowed for the evaluation of activity levels captured concurrently with GPS data as well as to identify activity occurring without GPS data.

RESULTS: Table 1: Cumulative GPS Trip Data and sample data capture.

CONCLUSIONS: Based on the findings from this study it is evident that the use of GPS/GIS and accelerometer technologies is an effective procedure to both quantify and depict travel behaviors and activity levels associated with visually impaired adults. Based on the results of this preliminary study, a 3 year regional study quantifying the impact of Blind Rehabilitation on travel and physical activity has been funded and is in progress (N=225).

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Test-retest reliability of ambulatory activity monitoring in 74 patients with Parkinson's disease

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INTRODUCTION: Assessment of real world performance of physical activities is important in determining the efficacy of training interventions in Parkinson's Disease. This study investigated the 3-week test-retest reliability of assessing functional daily walking activity in the natural environment by applying ambulatory activity monitoring (AM).

METHODS: This reliability study was conducted as part of the RESCUE trial, a large multi-centered RCT on home cueing training in patients with Parkinson's Disease in three European countries [1]. Activity monitoring was done twice with a 3 week interval in the patients' home environment. The Vitaport ® activity monitor (Temec Instruments B.V., Kerkrade, The Netherlands) was used to record the postures and motions of subjects on each assessment day. The system was applied in the morning and removed in the evening of each assessment day. Start time and day of the week were kept constant. The AM consisted of a set of 5 piëzo-resistive, dc-coupled accelerometers placed on the legs and chest, connected to a portable data-logger. Postures and motions were classified off-line as static activity and dynamic activities, using Vitagraph ® software. The variables investigated were: % dynamic activity, % static activity, % sitting, % standing, % walking, number of walking periods > 5 sec (W>5s) and number of walking periods > 10 sec (W>10s). Intraclass correlation coefficients (ICC) were calculated with a two-way random effects model and an absolute agreement definition. The Bland and Altman method was used to analyse the limits of agreement.

RESULTS: A total of 74 patients completed both monitoring sessions. The test-test ICC's were as follows:% dynamic activity (ICC=.81, p<0.0001), % static activity (ICC=.76, p<0.0001), % sitting (ICC=.60, p<0.0001), % standing (ICC=.50, p<0.0001), % walking (ICC=.72, p<0.0001), W>5s (ICC=.68, p<0.0001), and W>10s(ICC=.73, p<0.0001). Bland and Altman analysis showed acceptable homogeneous distribution of differences for all variables.

CONCLUSIONS: Moderate to very good reliability of AM over the 3 week period between assessments was found: ICC's ranged from .50 for standing to .81 for dynamic activity. The lower ICC's for standing and sitting may be related to variations in supine sitting being classified as lying or very slow walking as standing or general movement respectively. These classifications may need to be improved by modification of the software algorithms. Ambulatory monitoring is deemed suitable for use as an outcome measure in intervention studies in patients with Parkinson's Disease, as it has acceptable stability over a 3 week time period.

ACKNOWLEDGEMENTS: The RESCUE project was funded by the EU Framework V funding, QLK6-2001-00120.

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Evaluation of postural instability in diabetic patients with peripheral neuropathy using accelerometers

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INTRODUCTION: Approximately 2.8% of the population suffers from diabetes [1] and more than 50% of diabetic patients > 60 years old are affected by peripheral neuropathy (PN) [2]. One of consequences related to PN is postural instability [2]. A new method using accelerometers has been proposed as a suitable measure of balance control [3]. The aim of this study is to investigate standing balance of diabetic patients with and without PN using accelerometers.

METHODS: Three groups were included in this study: (1) 12 controls participants, (2) 12 patients with diabetic Type 2 without PN and (3) 12 diabetic Type 2 patients with PN. Three accelerometers have been used to collect trunk and ankles linear accelerations (Physilog®, BioAGM, CH) at a frequency of 200 Hz. Medial lateral (ML) and anterior posterior (AP) acceleration components have been considered at the trunk and AP component at both ankles. All participants were tested in a quiet standing position for 30 seconds in two specific conditions: eyes opened (EO) and eyes closed (EC). Linear acceleration ranges and root mean squares (*RMS*) have been calculated for each signal. Since no difference has been detected between right and left ankles data, ankles parameters have been averaged. All parameters were compared between groups for both conditions using a one way ANOVA. A Tuckey post-hoc test was performed when necessary. A significant *P* value was set to 0.05.

RESULTS: A significant difference was found between groups for the range of the AP trunk acceleration during EO condition with higher values for PN patients ($P < 0.001$). During the EC condition the range and *RMS* of the ML trunk acceleration have also shown significant differences with higher values for the PN patients. All ankle parameters for both conditions were significantly different between groups showing higher range and *RMS* values for diabetic patients with PN. Figure 1 shows range values of the AP trunk acceleration for each group and for both conditions.

CONCLUSIONS: Results confirm that diabetic patients with PN have greater postural instability with higher acceleration values than control group and diabetic patients without PN. Differences between groups were more important during the EC condition noting 5 significant parameters compared to 3 during the EO condition. Accelerometry represents a suitable and simple method that could be used in a clinical setting as a measure of balance control for diabetic patients.

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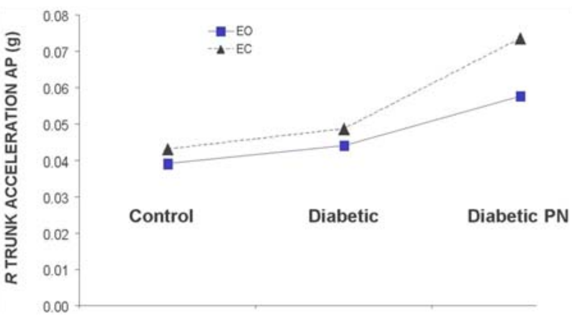

Fig.1 Range (*R*) of the AP trunk acceleration for each group for eyes opened (EO) and eyes closed (EC) conditions.

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Video-based validation of single-sensor accelerometry for detecting lying, sitting, standing and walking in older adults and Parkinson's disease patients

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INTRODUCTION: To assist older people in maintaining independent mobility, effective interventions are needed as well as methods for assessing and monitoring mobility. Although basic solutions are available for assessment and monitoring of mobility related activities based on body fixed sensors [1], available literature shows very few examples of evidence-based clinical applications of these methods in older people [2]. The practical feasibility of applying monitoring technology over longer durations will be enhanced if the complexity of instrumentation can be reduced. Therefore, the aim of this study was to examine the validity of a single-sensor accelerometry approach for detecting postures and walking in older adults and Parkinson's disease (PD) patients.

METHODS: The validity of the DynaPort MiniMod MoveMonitor® [3], an accelerometry based method for the detection of lying, sitting, standing and walking, was studied by using video observation as a reference method. Different assessment protocols were used in 25 older adults (OA) without mobility impairments and in 35 subjects with PD. First, subjects were instructed to perform specific activities in a fixed order, thereafter subjects were free to choose to perform certain activities in a self-chosen order. Assessments were made in a laboratory environment as well as in the home situation of some of the subjects. Activity assessments included walking episodes of different lengths and durations, sitting in a chair, stair walking, lying in bed in different positions, and walking while carrying. In their home environments, subjects were asked to perform some of their usual domestic activities such as doing dishes, walk about (in house), watering the plants, doing laundry, garden work etc. During all assessments, subjects wore a MiniMod [3], a small tri-axial accelerometer, at the lower back. All activity sequences were videotaped, and the video data were scored by two independent observers. Blinded analyses of the acceleration data [3] resulted in the allocation of one of 5 activity categories to time (i.e.

lying, sitting, standing, walking or "other"). The resulting activity sequences were compared to video observations by calculating the degree of correspondence. Both the overall correspondence of activity sequences as well as the correspondence for the specific postures and walking was determined.

Results: The first results in 10 OA and 10 PD patients show similar outcomes. The average overall correspondence between accelerometry based results and the video-based traces of activities in time was 83% (OA) and 85% (PD) for instructed activity sequences and 91% in both OA and PD for the self-chosen activities. On average, episodes of lying were detected well (i.e. ≥99%), whereas sitting (≥60%) and standing (≥70%) showed a moderate correspondence. These lower percentages were caused by the fact that in some subjects (OA as well as PD) short episodes of sitting or standing could sometimes remain undetected. Although short walks were sometimes categorised in a category "other activity" rather than "walking", episodes of walking were detected well in OA (86%) and PD (91%).

Conclusions: These first results demonstrate the potential value of an accelerometry based method for monitoring postures and walking in OA and PD. Particularly, the results of detecting episodes of walking are promising. Detected gait episodes can be analysed further to assess qualitative as well as quantitative aspects of walking [1,4].

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Assessment of postures and movements during daily life with clothes attached sensors

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Introduction: The effectiveness and success of activity monitoring during daily life crucially depend on the ease with which clients can use the system. Several studies have shown that it is possible to reliably monitor physical behaviours of ambulant clients by means of accelerometers that are tightly attached to the lower part of the body [1,2]. Ease and comfort of use are compromised if the sensors must be tightly fixed to the body at precise points. In daily life, the majority of the activities involve one of the following basic postures and movements: sitting, standing, lying, walking and bicycling (the basic set). The purpose of this study is twofold: (1) to assess the accuracy with which the basic set of postures and movements can be detected in daily life using accelerometers attached to the participants' clothes and (2) to determine the minimum number of sensors necessary for this task.

Methods: 10 participants were tested in 3 different situations: fully controlled movements and postures according to a protocol (10 participants), controlled natural activities (5 participants), and daily life activities in a natural environment (5 participants). Two sets of three 3-D acceleration sensors (Minimod, Mcrobberts) were used to assess the postures and movements of the participants. One set was tightly fixed to three body segments (both upper legs and the trunk (sternum)). The other set (called loose below) was attached to the clothing of the participants (sensors were put in both pockets of the subjects' trouser and one was attached to the belt). Hidden Markov Models (HMM) were trained and tested with the data of the controlled movements and postures. The controlled natural and daily life activities were evaluated by comparing the agreement between classification output of models trained by the loose and fixed sensor configuration set. Four different types of parameters were used as input parameters of the HMM for each sensor (12 total). One parameter represents the orientation of the sensor; two parameters were derived from autocorrelations; one parameter was derived from the Fast Fourier Transform. The leave-one-patient out method was used to create person-independent models.

Results: For the controlled movement and postures recordings, there was no significant difference in classification performance between the loose (96.3% correct classification) and fixed sensor configuration (98.0% correct classification). The loose sensor set showed an agreement of 0.86 with the fixed sensor set for the daily life measurements. The classification of the loose sensor set was not in agreement with the fixed sensor set for bicycling and lying for 2 out of 5 subjects. The disagreement between the sensors was in most cases a result of the different position of the trunk sensor between the loose (belt) and fixed (sternum) set. A paired *t*-test did not show a significant difference in classification between the full 3 sensors set and a two sensor set (one upper leg and trunk) for both the fixed and loose set. The use of one sensor set gave a decrease in classification performance of 18% when the sensor was attached to the upper leg and 27% for one sensor on the trunk.

Conclusions: The acceleration signals from sensors worn in clothing are sufficient reliable for detection of postures in assessing postures and movements in daily life. A minimum set of 2 sensors either attached to the body or clothes are required for assessing the basic set of postures and movements in daily life.

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Self-reported activity restriction due to fear of falling: how objective?

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INTRODUCTION: Prevalence of fear of falling is high in older people, and has been related to several consequences, including activity restriction, functional decline, and reduced quality of life. However, the relationship between fear of falling and physical activity (such as number of transitions, time spent walking) has been essentially assessed using self-reported measures of physical activity. It remains unclear whether subjects who report activity restriction from fear of falling are truly less active. Using objective measures of daily activity might provide more accurate information about this relationship. The aim of this study was to compare physical activity measured by an ambulatory monitoring system between groups of elderly persons reporting different levels of fear of falling (associated or not with activity restriction).

METHODS: To gather a study population reporting various levels of fear of falling and activity restriction, a convenient sample of participants aged 65 years and over was recruited from two populations: a) community-dwelling persons and b) patients admitted to a post-acute rehabilitation facility. Participant's level of fear was assessed using a standardized questionnaire; measures of physical activity were performed using the Physilog® [1] system over two 8-hours periods of recording over 2 consecutive days. Posture allocations (lying, sitting, standing) and walking periods were determined based on kinematics of trunk segment detected by an inertial sensor.

RESULTS: Participants (N=77, mean age 77.7±7.3, 59.7% women) were divided into 3 groups, no fear of falling (N=55), fear without restriction of activity (N=13), and fear with restriction of activity (N=9). There was a statistically significant trend in most physical activities parameters (longest walking period, proportions of standing and walking time, numbers of transitions per hour) across the three groups. In contrast, sitting time only differed significantly between fearful (with or without restriction) and not fearful groups, and lying time only differed when activity restriction was present (see figure 1).

CONCLUSIONS: These results show objective variations in physical activity according to self-reported fear of falling and activity restriction. However, there is a large overlap in levels of physical activity between groups, suggesting that additional factors play a role in the pathway leading to decreased activity in fearful older people. Further studies with larger samples would be needed to investigate the significance of the differences in sitting and lying times among levels of fear.

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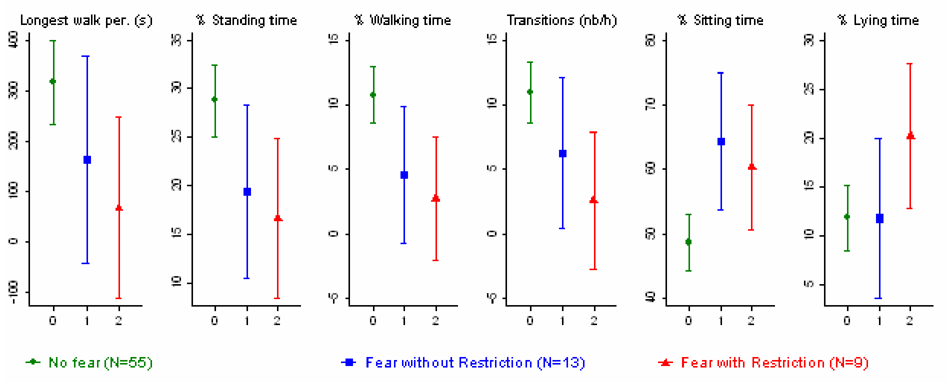

Fig.1 Mean and Bootstrapped 95%-CI for Physical Activity measures across groups

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Pervasive informatics and persistent actimetric information in health smart homes: different approaches

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INTRODUCTION: This paper discusses the possibility to obtain reliable pervasive information at home from a network of localizing sensors allowing following the different activity-stations at which a dependent person can be detected. Since 12 years ([1-3]), numerous experiments have been achieved for monitoring activity patterns and trends of dependent individuals, especially older and handicapped adults, at their home. For acquiring data necessary to permit the alarms triggering, various sensors dedicated to the localization of person at his/her home or surroundings. These localizers can be located (i) on the person's body (e.g., GPS, accelerometers...), (ii) at home (on the walls: e.g., infrared or radar detectors; on the ground, the bed or the chairs: e.g., pressure sensors, on the doors: e.g., magnetic switches) or (iii) outside (in gardens and streets: e.g., video-cameras).

METHODS: The data recorded could be treated as time series as the sequence of colour coding numbers of balls (symbolizing activity-stations) taken in a Polya's urn, in which the persistence of the presence in an activity-station is represented by adding a number of balls of the same colour as the ball just drawn ([5]). The sequence could also represent historical data from a model, deriving from language models and markovian processes existing in speech recognition research, where the persistence is the probability to stay at the same activity-station ([6]). Other models can also be used as well as the mean time passed or the remaining time in the activity-station. We compared to use the most representative one.

RESULTS: Using statistics, the best model offers up to 98% of good prediction location, considering only the last second of location but distinguishing days of week. Other models need to be improved. We discuss the pertinence of such procedures to early detect sudden or chronic changes in the parameters values of the random process made of the succession of ball numbers. We will use the best procedure to trigger alarms, which will occur when an incorrect prediction is made, or when the person persists at the same station more than the mean time passed in this station, or when the remaining time is passed.

CONCLUSIONS: The sensors network is very important to monitor body posture, activity and gait of dependent people inside home or outside. If the space/time data are acquired on healthy elderly adults or on patients who suffer from neurodegenerative diseases, the sensors recording must be very well calibrated, to give birth to specific profiles concerning the time series which correspond to the successive locations of the dependent person in rooms inside home or in specific places inside a room ([4]). Simpler than Polya's urns derived approach, the Markovian approach seems to be a good way of location modeling. Other models need to be improved to concurrence it. A big hope comes from the ambient information techniques to be able to detect a sudden fall on the ground or a progressive stereotyped behavior (for the early diagnosis of chronic neurodegenerative diseases like the Alzheimer or Parkinson ones).

ACKNOWLEDGEMENTS: AFIRM Team from TIMC-IMAG Laboratory for HIS data records.

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Wearable system for foot kinematics and pressure measurements during gait

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INTRODUCTION: In this study we introduce a wireless and portable system for gait analysis that was designed and preliminary validated. The system features two multi-sensor nodes, one for each foot. Each node can provide inertial information, by means of a 3D Inertial Measurement Unit (ADIS16350, with 3D accelerometer and gyroscope), positioned approximately at the level of the Achilles tendon, and pressure beneath the foot, by means of an insole with 24 pressure sensors placed on the most relevant foot-shoe contact region (Paromed). An external gateway acquires data at 83Hz from the two nodes and performs data storage for off-line processing.

METHODS: The preliminary validation of the system was performed through fusion of pressure and inertial information during gait, with the aims of detecting swing and support phases and of estimating the foot inclination. Data were acquired on a young healthy subject who walked along a hallway for about 10 m, performing 3 repetitions of the task. Identification of heel-strike and toe-off was performed considering pressure sensors and the acceleration along the vertical direction. Different

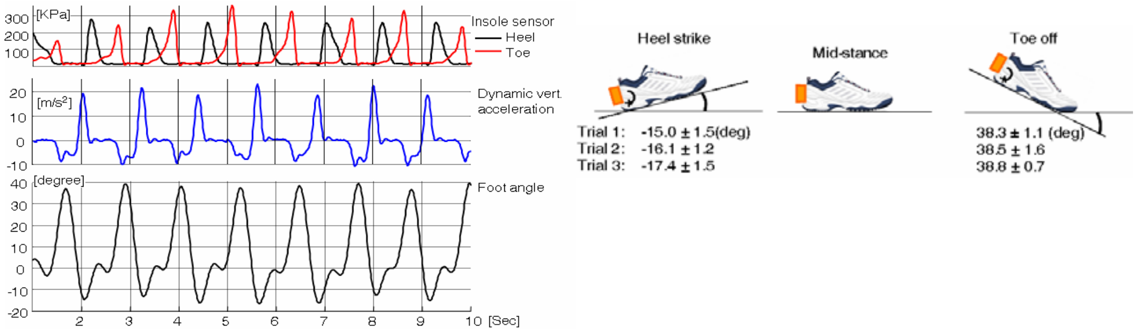

Fig.1 Left panel: representative signals. Right panel: foot angle inclination

stages of the support phase were identified through the pressure sensors and the dynamic component of the vertical acceleration. Inclination angle of the foot was estimated from the angular velocity of the gyroscope by means of an integration procedure, optimized considering the redundancy of sensors data and the gait recurring pattern [1-2]. In particular, the mid-stance phase was used to cyclically reset the integration algorithm.

RESULTS: Main results are shown in Fig. 1 (left panel: representative data of one trial; right panel: averaged data along each trial). The reliability of the results proved the adequacy of the system and of the developed procedure for foot angle estimation. Without such procedure, angle drift from actual value could even reach 15° during a single trial (lasting about 10 s).

CONCLUSIONS: Results suggest that the system with the appropriate algorithms based on sensors data fusion can be an adequate tool for gait analysis, and it can provide information both on foot-to-floor interaction and on foot kinematics, with applications in the evaluation of functional impairments to the motor system and rehabilitation outcomes. The development of more advanced procedures for kinematics estimate and their validation, by means of gold-standard systems, are under study.

ACKNOWLEDGEMENTS: Supported by the EU-FP7, n° 215493-ICT - SMILING project

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Quantitatively assessing foot placement during real-world rollator use

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INTRODUCTION: Understanding how walker-dependent individuals position their feet during the use of a rolling walker (i.e. rollator) could provide further insight into how these mobility aids enhance the stability of balance-impaired individuals. During gait, mobility impairments often become manifested as changes in step width or step width variability [1]. Therefore, by developing a method to quantify these gait characteristics during rollator walking, without the use of a laboratory-based motion capture system, we may enhance our understanding of how these devices influence their user's gait patterns in a real-world environment. The purpose of this study is to assess the validity of a novel approach to extracting step width from video data recorded directly on-board an instrumented walker (i.e. iWalker) while it is being used by able-bodied young adults. This study will establish the foundation for future work in patient populations with balance impairments, such as individuals with a traumatic brain injury (TBI), stroke, or neuromuscular disorder.

METHODS: Two able-bodied young adults were instructed to ambulate across an in-lab walkway with varying step widths: preferred, narrow, and wide. These step widths were measured concurrently using a digital video camera on board the iWalker (i.e. the footcam) and a seven-camera Vicon MX Motion Capture System as a reference. The footcam was oriented backwards towards the user's feet such that it was able to capture the position of toe markers during walker-assisted gait (Fig. 1). Parallax error in the video images was rectified and the two-dimensional coordinate position of the markers extracted using Peak Motus (Vicon, U.S.A.). Step widths were then calculated (Fig. 2) and compared with those obtained using the Vicon system (Fig.3).

RESULTS: Initial results indicate that the footcam-based step width calculations correlated strongly with those computed by the Vicon system in the lab (R^2=0.9588) (Fig.3). As a result, we believe that this method can be used to provide a quantitative assessment of foot placement during iWalker use.

CONCLUSION: Our camera-based approach to calculating step width provides an accurate assessment of foot placement during rollator use and may be used in future studies to identify differences in how this device is used by patient populations in real-world environments.

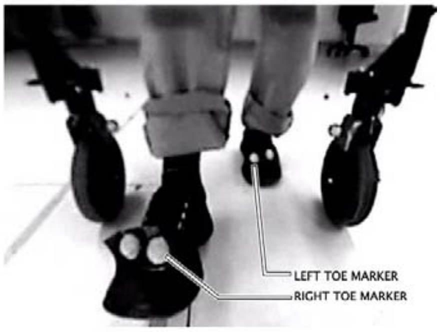

Fig. 1 Footcam view of toe markers (left)

Fig. 2 Method used to calculate step width from video data (middle)

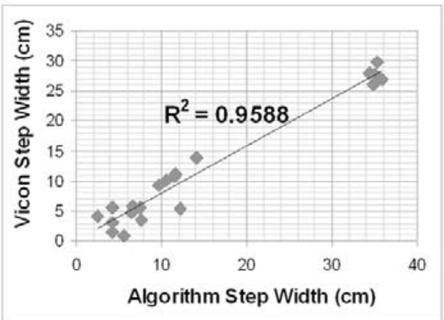

Fig. 3 Comparison of step widths calculated by the algorithm and Vicon (right)

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Detection of lying, sitting, standing and locomotion under free living conditions: validation of a one sensor versus multiple sensor approach.

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INTRODUCTION: Objective measurements of physical activities under free living conditions are important because physical activity is a leading health indicator. With the exception of some studies that use only one sensor at the sternum or at the leg, most methods for detecting postures and locomotion are based on sensors on two or more body segments. Recently, an accelerometry based method for detecting lying, sitting, standing and locomotion, was developed based on one light measurement unit (45 grams) fixed in a belt around the waist. The aim of this validation study is to determine whether the same accuracy can be reached with instrumentation on the trunk compared to instrumentation on the trunk and leg.

METHODS: Habitual daily life activities were studied during 24 hours in 6 young adults (mean age 24.2 ± 5.2 yrs) and 6 very old adults (mean age 87.3 ± 4.2 yrs). In all subjects, simultaneous measurements were made with the DynaPort® MoveMonitor® and the DynaPort ADL-Monitor. The latter, a well validated activity monitor [1-3], was used as a criterion. Both measurement systems were synchronised at start. Small differences in measurement length were corrected by resampling. Special Matlab software was developed to synchronise and resample the data, and to compare the two data-sets which were available in each subject. For each second of available data it was determined whether the two-data sets identified the same activity category. From this, the proportion of agreement was calculated over all activities and per activity category. The minimal validity (Vmin) is the total time the two systems agree in the total measurement about all classes at the same second expressed as the percentage of the total measurement time. The maximal validity (Vmax) is the total time the two systems agree in the total

Table 1: Minimal validity (Vmin) and maximum validity (Vmax).

	All subjects (n=12)		Young subjects (6)		Old subjects (6)	
	Mean	sd	Mean	sd	Mean	sd
Vmin	89.9%	6.0%	92.8%	2.6%	87.0%	7.2%
Vmax	95.9%	4.2%	97.2%	2.0%	94.7%	5.6%

Table 2: Sensitivity, specificity and error of the agreement (n=12)

	Sensitivity	sd	Specificity		Error	sd
Lying	98.9%	1.4%	98.2%	2.0%	0.9%	1.2%
Sitting	85.2%	8.6%	95.0%	3.7%	3.8%	4.2%
Standing	75.7%	10.0%	93.2%	4.9%	3.2%	3.9%
Locomotion	87.8%	9.1%	99.7%	0.2%	0.2%	0.2%

measurement about all classes (i.e. not necessarily at the same second) expressed as a percentage of the total measurement time.

RESULTS: Mean overall agreement was 89.9% (Table 1), with agreement for the young adults a bit higher (92.8%) than for the very old adults (87.0%). Sensitivity ranges between 75.7% and 98.9% and specificity ranges between 93.2% and 98.2% (Table 2).

CONCLUSIONS: Good agreement was found between both systems, with very small differences for young and very old adults. A one sensor approach has many advantages over a multiple sensor approach which makes this a promising tool. Future studies have to confirm validity of the method in different populations.

ACKNOWLEDGEMENTS: This work was supported by the European Commission (FP6 project SENSACTION-AAL, IST-045622).

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Accelerometry-based prediction of center of pressure during dynamic balance tasks

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INTRODUCTION: One common way to assess postural responses to dynamic balance tasks requires a movable force platform and a motion analysis system to measure center of pressure (COP) excursion and kinematic strategies. Such equipments although very accurate are expensive and not portable. In a recent study [1] we showed that we can obtain a good prediction of the COP by means of accelerometers during spontaneous body sway. We aim to develop here an accelerometry-based, general prediction model which can be used also during dynamic balance tasks.

METHODS: Three subjects (29.3±3.2 years) wore 4 MTX Xsens sensors, mounted by means of velcro belts on the following sites. Posterior trunk: L5 and C7 levels; lateral aspect of the right leg: thigh and shank. Subjects stood on a force platform (BERTEC 4060A) that could be moved forward and backward. A series of platform translations was elicited to generate a continuous perturbation in a frequency range 0.5 - 2 Hz in 10 trials, each of 60s duration. Data were acquired and synchronized at 50 Hz. We wrote the dynamics equations for a four-segment, shank-thigh-lumbar-cervical, inverted pendulum model of the body, relating the relevant kinematic variables with the accelerometers' outputs. The COP could be expressed as the linear combination of the four accelerometer outputs weighted by zero-phase transfer functions. Each of these transfer functions was approximated by a centered, finite impulse response (FIR) filter with order N=50. In this way we obtained a simplified linear model, valid for small angular deviations in the sagittal plane, to predict COP from the measured accelerations. We estimated the filter parameters by minimizing the sum of the squared errors between predicted and measured COP in the first half of each trial (description). Then we used the same parameters to predict the COP in the second half of the trials (1st prediction). Also, we used parameters estimated on one trial to predict the COP in the remaining trials of the same subject (2nd prediction). Finally, we used parameters estimated on a combination of slow-fast trials to predict the COP in the remaining trials of the same subject (3rd prediction). For each trial we calculated the root mean square error (RMSE) between the COP measured by the force plate and the COP predicted with the model.

RESULTS AND CONCLUSIONS: The predicted COP is in good agreement with the measured COP also in the trials with higher frequency content. The mean value of the RMSE error is in the order of 3.6 mm (ranging from 1.4 mm in the description error of Subject1 to 5.7 mm in the 2nd prediction error of Subject 3) when the COP excursion was of 14 cm (ranging from 6 to 18 cm). Mean RMSE values for each error and subject are showed in figure 1. As expected, the RMSE is higher in the 1st and 2nd predictions with respect to description, but differences are not significant. An intermediate result is obtained for the combined slow-fast dataset. Our preliminary results are encouraging: accelerometry-based COP prediction can be used as a force plate substitute to assess balance in static or dynamic conditions in an easy, flexible and portable way.

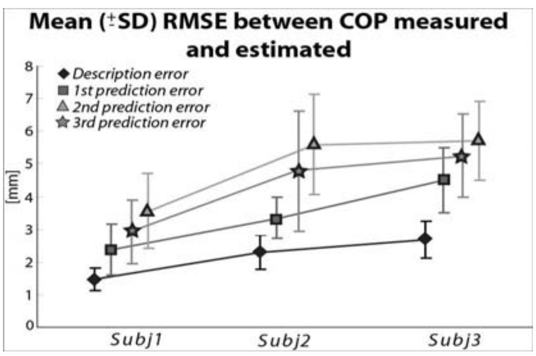

Fig. 1

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Posterior shank resistance modifies the biomechanics of sit to stand

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INTRODUCTION: There are many individuals who need to alter their biomechanics of sit to stand (STS) in order to create and control the transfer of momentum required for a successful rise. A chair that provides resistance to the posterior shank may add stability and may alter forces and joint angles required for a successful STS. It is our hypothesis that STS at a slow speed with the assistance of a posterior shank resistance (PSR) will (1) decrease hip flexion motion (2) decrease hip extension torque and (3) increase knee extension torque compared to normal STS.

METHODS: Nine healthy male volunteers performed 10 STS trials with a 54 bpm metronome in PSR and no PSR conditions. Kinematic and kinetic data were collected and statistics analyzed using a student's t-test with p<.05 for significance for variables of interest.

RESULTS: In the PSR condition, participants demonstrated significantly less hip flexion motion (p<.05), less hip extension torque (p<.05), and greater knee extension torque (p<.05) compared to no PSR. In the PSR condition, center of mass moved with a simultaneous horizontal and vertical progression compared to distinct horizontal and vertical phases observed in normal STS.

CONCLUSIONS: By providing a constant point of stability, a slow continuous movement is achieved while generating less hip motion and torque. The above results indicate that using a PSR alters the biomechanics of STS by re-weighting the torque from the hip to the knee. PSR may aid those with slow speed of movement, limited hip flexion, hip extensor weakness, and instability during STS.

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Gait assessment of processed socks with ankle taping

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INTRODUCTION: Taping is a procedure that to physically keep in place joint at a certain position. This reduces pain and aids recovery. So, we expected that the taping is useful not only in sports scenes but also in daily life. However, anatomical and kinematical knowledge and skills are necessary for taping. Therefore, we looked for another easier method to provide the taping effects in order to prevent the ankle sprain. Here, we focused on socks frequently wore in the daily life and produced the special socks which can induce ankle eversion to prevent ankle inversion sprain. We call the socks "Taping Socks". The purpose of this study was to verify the influence on the ankle range of motion by the use of Taping Socks during gait.

METHODS: 6 healthy volunteers (age, 19.3 ±1.9 years; height, 170.3 ± 2.3 cm; weight, 63.0 ± 7.9 kg: mean ± standard deviation) participated in this study. Informed consent was obtained in writing from all subjects before the study.Participants were tested under three gait conditions in random order: 1) barefoot, 2) taping; tape was applied, stirrups, heel locks and figure eights, and 3) the Taping Socks; eversion processing was spiralled up from lateral of fifth metatarsal head to medial of lower leg (Fig. 1). Participants completed three gait trails respectively under three gait conditions. Ankle range of motion was measured from the frontal and sagittal plane by electrogoniometer (Biometrics Ltd., UK), and the force plate system (ANIMA Corp., Japan) was synchronized with the electrogoniometer. In the data analysis, we extracted the maximum and minimum values, and calculated the mean values. After these data were compared using one-way analysis of variance, the Ryan method was used for the multiple comparisons.

Fig. 1 Taping Socks

RESULTS: In ankle eversion range of motion, gait conditions with the Taping Socks (p<0.009) and taping (p<0.009) increased significantly to gait condition with barefoot. In the force plate system, the minimum value of vertical force (p<0.004) on gait condition with the Taping Socks decreased significantly, and the maximum value of mediolateral force (p<0.010) increased significantly to gait condition with barefoot.

CONCLUSIONS: Results of this study indicate that the Taping Socks have the effects of induction of ankle eversion as well as taping during gait. Therefore, wearing Taping Socks are an easy and effective way of protecting the ankle ligament against excessive strain in daily life.

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Examination of posture in transfemoral amputees: the use of 3-D back shape measurement

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INTRODUCTION: Care for persons with lower limb loss wearing a trans-femoral prostheses implies not only the inspection of the prosthesis and of ambulation with the device but also the check of posture of the standing patient and objective recording of the sagittal curve, pelvic tilt and pelvic inclination. These measures give important indications on proper alignment of the prosthetic device and the correct adjustment of its length to avoid leg length asymmetry beyond the necessities for ambulation using a lower limb prosthesis. Generally these examinations are done clinically. However, the needs for objective and automatized documentation call for novel techniques as an alternative, for example 3-D measurement of the back surface and a pertinent mathematical analysis. A novel method for the examination of posture of transfemoral amputees is presented and first results are given.

METHODS: 3-D measurement of the back is done by rasterstereography [1], where data capture is done by a single shot. The data allow for the mathematical reconstruction of the surface and of distinguished lines like the the sagittal profile. In addition, selected landmarks on the back surface can be identified and localized with high precision, for example the posterior superior iliac spines landmarks. Based on the coordinates of the landmarks and on the surface orientation in these points, angle-measures for the pelvic tilt, pelvic inclination and pelvic torsion can be calculated [2]. A test for the feasibility of the method of the measures was performed with 10 amputees wearing a transfemoral prosthesis. To test the reliability of the measures intraindividual series of 12 measurements with varied leg length compensation were made and standard deviation of the regression line fitting the data is calculated.

RESULTS: The mean values for pelvic inclination, pelvic tilt and pelvic torsion (Fig. 1) without leg length compensation were: +21.8°, +3.1°, and +0.6° respectively. The positive signs indicate, that the sagittal profile in the sacral region is inclined forward, that the hip bone on the intact side is higher and is rotated backward than on the contralateral side. The standard deviations for these measures are: 1,07°, 0,49° and 0,56° respectively, indicating a high reliability of the measures.

CONCLUSIONS: Back shape measurement and appropriate mathematical analysis provide feasible and reliable methods for the assessment of posture in inspecting prosthetic provision.

Fig. 1: Leg length compensation affects pelvic torsion.

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Effect of leg length discrepancy on load distribution in transfemoral amputees

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INTRODUCTION: A basic objective in fitting a lower limb prosthesis is to provide comfortable weight bearing - either in two-legged stance or during the stance phase of gait. When standing on both legs an amputee who feels the risk that the prosthesis beneath him might collapse, will transfer as much body weight to the contralateral side to avoid any risk. Thus, the weight distribution will be disturbed to the disadvantage of the contralateral side which typically takes over 60% of body weight. Other reasons for an uneven load distribution in stance might be either the proprioception in the contralateral foot helping to maintain balance or an uncomfortable fit of the socket. The long-term effect of uneven load distribution may be an increased risk that overload injuries like arthosis might develop and thus should be prevented. It was the aim of this study to find out whether manipulation of leg length discrepancy between the amputed and intact side might have an effect on the load distribution.

METHODS: 10 unilateral above-knee amputees were recruited when attending the policlinics for prosthetic and orthotic management. The mean age of the patients was 56 years. In the mean they had used their prosthesis since 21 years. Total load and load distribution was measured using a force platform (Fig. 1) dedicated for Prosthetics & Orthotics purposes (LASAR Posture, Otto Bock). Leg length discrepancy was changed in steps of 5 mm starting with -35 mm (i.e. lifting the prosthetic side by this amount over the contralateral side) and ending at + 20 mm, i.e. lifting the intact side by 20 mm. For each patient and for the whole cohort a regression analysis was performed calculating slope and offset. Statistical analysis was done with commercial software.

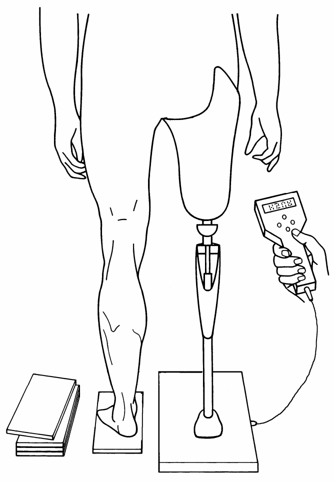

Fig. 1: Set-up for measuring load distribution

RESULTS: In the mean a loading of 40% of body weight is observed on the prosthetic foot. In the mean no effect of the height of leg length compensation to the load distribution can be observed. However, phenomenologically two distinct groups can be distinguished: 6 patients significantly ($p \leq 0,1\%$) showed a positive reaction, i.e. increased loading of the prosthesis when lifting the amputed side. However, in no case an equal loading - i.e. 50% on both legs - was achieved. In 4 patients lifting the amputed side produced a negative reaction, i.e. a significant ($p \leq 0,1\%$) unloading.

CONCLUSIONS: Leg length compensation has an effect on the load distribution. However, the effect is not uniform in different patients, instead two groups with contrary reaction were identified.

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Modern above-knee prostheses: the effect of yielding and bouncing on the biomechanics of gait

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INTRODUCTION: The advent of modern knee prostheses has opened up a new quality in the provision of above-knee amputees. This can be demonstrated by means of kinetic and kinematic measurements. Amputees achieve significantly more dynamic combined with sufficient security. we investigated the influence of knee flexion under load - wich can be limited (bouncing) or unlimited (yielding) - on the biomechanics of gait. Special attention will be drawn to microprocessor controlled prostheses.

METHODS: So far 82 transfemoral amputees with mobility level 1-4 have taken part in our study. They were aged between 17 and 91 years with a mean age of 54 years. Optimum fitting of the socket was supervised by a certified prosthetist-orthotist using the *l.a.s.a.r. posture* (otto bock). This device combines a ground reaction force platform with an optometric laser system. After a medical examination by an orthopaedic surgeon, biomechanical and clinical measurements were taken using the opto-electronic gait analysis system *(vicon v460,* 6 cameras, 50hz) in combination with 2 *kistler* force plates (9286 aa) to obtain kinetic and kinematic data. Altogether we investigated 21 different prosthetic knees. They range from the locked-knee type over mechanically passive prostheses to the microprocessor-controlled variable-damping knee.

RESULTS: Knee flexion under load leads to more natural looking kinetics and kinematics of the hip and knee. In the ground reaction force the absorbing effect of prostheses with yielding and bouncing can be clearly seen. If the prosthetic knee does not allow knee flexion in the beginning of the stance phase the corresponding joint moment is completely negative (extension moment). On the other hand already a slight bouncing or yealding can lead to positive flexion moments (Fig.1).

CONCLUSIONS: Knee flexion under load leads to a more natural gait of the amputee. Especially the microprocessor-controlled knees offer additionally a high level of security. The gait of the amputee becomes more symmetric and physiological. For the amputee this means not only comfort but also a reduction of effort. Furthermore it implies that the amputee feels safe because he uses the full capacity of the prosthetic knee. If he tried or had to secure the prosthetic knee additionally with his stump, again a negative knee moment occured. Amputees gain manifold benefit from knees wich allow knee flexion under load. It allows them to unload the contralateral side and to walk with less effort. Furthermore they are able to walk ramps and descend stairs.

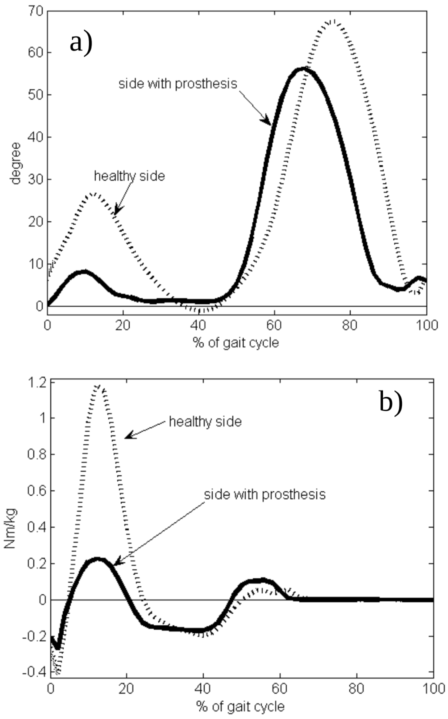

Fig.1 prosthetic knee with flexion under load: a) measured knee angle b) calculated knee moments - healthy side (dotted line), prosthetic side (solid line)

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Indications for electronic knees for above-knee amputees: clinical and biomechanical aspects

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INTRODUCTION: The advent of electronic knee prostheses, i.e. the computer control of stance and swing phase, has opened up a new quality in the provision of above-knee amputees. All in all, a more secure, natural and efficient gait is expected. The technology of the two available systems - C-Leg (Otto Bock) and Rheo Knee(Össur) - differs in some details. Therefore, from the biomechanical and clinical viewpoint a comparison is important in order to find out, whether differences between the two systems can be detected and how they affect the provision of the patient. The purpose of the study is to compare and evaluate the electronic knees in terms of functional improvement. The second aim of the study is to critically review the indications for the electronic knees and to determine if these indications are appropriate.

METHODS: So far 79 trans-femoral amputees with mobility level 1-4 took part in the study comparing electronic and mechanical knees. Neither of these patients was using regularly one of the two tested microprocessor joints. As a prerequisite, optimum fitting of the socket had to be provided. This was supervised by a certified prosthetist-orthotist using the L.A.S.A.R. Posture (Otto Bock). After the examination by an orthopaedic surgeon biomechanical measurements were taken using an optoelectronic gait analysis system (Vicon V460) in combination with 2 Kistler force plates and the GAITRite System (SMS Technologies). Clinical results were achieved by an indoor and outdoor parcours, where the patient e.g. had to walk ramps, descend stairs and walk on different grouds. At last a questionnaire is filled out, asking the patients for their self perception of the electronic knee joints. Based on these data, the functional improvement is assessed.

RESULTS: For the study a list of 7 criteria of functional improvements is formulated. These were: Improvement of safety, unloading of the contralateral side, improved devided attention, harmony of gait pattern, variability of gait velocity, reduction of effort and abandonment of a stick on the contralateral side. Electronic knee-joints are recommended for amputees who meet more than three of the seven criteria. We found that nearly 80% of our subjects benefit from an electronic knee joint. No correlation was found for the mobilty level, time since amputation or reason for amputation. Our results indicate that patients with short stumps prefer the Rheo Knee because it requires less forefoot force to activate the swing phase. Elderly subjects and amputees with multiple disabilities prefer the C-Leg as they feel more secure. Sometimes athletic amputees dislike the C-Leg because they feel that it interferes with their intended movement.

CONCLUSIONS: The Rheo Knee is recommended for mobility levels 2 and 3 whereas the recommendations for C-Leg include mobility levels 3 and 4. We found that more patients with mobility level 2 have a benefit from the C-Leg as compared to the Rheo Knee while patients with mobility level 4 often prefer the Rheo Knee. So the mobility level alone can not be used as a predictor for a successful provision with an electronic knee. Instead of the mobility level other criteria like age, multiple disabilities but also coordinative and cognitive abilities including different combinations of them seem relevant for the optimal using of a prosthetic knee joint. Therefore a testing procedure and/or a testing period is obligatory. The advent of modern knee prostheses has opened up a new quality in the provision of above-knee amputees. Our study has shown that the 7 criteria of functional improvement assist successfully in the indication of electronic kne joints.

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The assessment of limits of stability in transtibial amputees in relation to the prosthesis and prosthetic foot alignment

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INTRODUCTION: Ones ability to perform maximal voluntary inclination of the centre of pressure (COP) within the base of support represents an aspect of dynamic postural stability. Lower limb amputation leads to postural stability impairment [1, 2]. Variations in prosthesis and prosthetic foot alignment in trasntibial amputees (TTA) influence the biomechanical aspects of gait [3]. The aim of our study was to assess the changes in limits of stability (LOS) in TTA in dependence on a prosthesis and prosthetic foot alignment.

METHODS: LOS were evaluated by the dynamic computed posturography using the SmartEquitest system of Neurocom®. LOS in TTA were tested within the framework of five following prosthesis and prosthetic foot alignments: an optimal, prosthesis length 1 cm shorter and 1 cm longer, prosthetic foot aligned to a plantar flexion (+5º) and to a dorsal flexion (-5º). Within the LOS, maximum excursion (MXE) of the COP on the basis of visual feedback and direction control (DCL) in anteroposterior and mediolateral directions were all assessed. MXE and DCL are given as a percentage, with a higher percentage showing better values. The experimental group included 12 unilateral TTA (age 55.3 ± 13.4 years, duration of prosthesis usage 10 ± 12.5 years). 9 healthy subjects (age 49 ± 11.5 years) made up the control group. For the statistical analysis of the examined data, the programme Statistica version 6.0 (Anova, Fischer LSD post hoc test) was used.

RESULTS: In the experimental group, the difference in the dependence on prosthesis and prosthetic foot alignment in every particular tested direction was statistically insignificant ($p<0,05$) for both MXE and DCL. For both tested parameters achieved TTA, there were higher values in mediolateral direction in comparison with anteroposterior direction. Within the voluntary inclination of COP in the posterior direction in TTA, DCL was significantly lower ($p<0,01$) in comparison with other tested directions independently on the prosthetic alignment. The parameter MXE of COP reached by TTA in this direction was significantly lower ($p<0,05$) in comparison with shift of COP aside amputated leg. For both tested parameters within the posterior inclination was the greatest variability of the tested values. The resultant values of MXE and DCL were higher in the control group as compared to TTA for all tested directions. However, this difference wasn't significant.

CONCLUSIONS: Variations in prosthesis and prosthetic foot alignment in experimental group of TTA didn't have an impact on limits of stability. For TTA subjects are maximal voluntary inclination of COP and direction control higher in mediolateral direction compared to anteroposterior direction. We did not discover any difference between TTA and healthy subjects in LOS.

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