KS-1

Neural mechanisms underlying balance control

J. Macpherson

Oregon Health & Science University, Portland, OR, USA

I will present a retrospective of concepts in posture and balance gleaned from my studies using the cat model of stance control. Topics will encompass sensory integration for balance and aspects of the neural control underlying posture. I will touch on the role of somatosensory inputs for triggering and directional tuning of automatic postural responses to sudden disturbances of balance and the function of vestibular inputs as a reference to earth vertical. Finally, I will address the concept of muscle synergies as endpoint force generators and speculate on the neural structures subserving this organzation.

KS-2

Motor patterns and programs for human locomotion

F. Lacquaniti

Neuroscience, University of Rome Tor Vergata, Rome, Italy

I will review the main kinematic and electromyographic patterns of activity associated with gait, using data from healthy adults, toddlers starting to walk, and spinal-cord injured adult patients. I will describe the kinematic coordination among the changes of the lower limb segments during straight or curved locomotion at different speeds, erect or bent posture, backward locomotion, and body-weight support. Next I will address the question of how the central nervous system coordinates muscle activity for locomotion. I will argue that motor programs may be considered as a characteristic timing of muscle activations linked to specific kinematic events. In particular, I will show that muscle activity occurring during human locomotion can be accounted for by five basic temporal components in a variety of locomotion conditions. Spatiotemporal maps of spinal cord motoneuron activation also show discrete periods of activity. Furthermore, the coordination of locomotion with voluntary tasks is accomplished through a superposition of motor programs or activation timings that are separately associated with each task.

KS-3

Preventing Falls in Older Adults: State of the Science

L.Z. Rubenstein

VA GRECC, UCLA Schol of Medicine, Los Angeles, CA, USA

Falls are extremely common in older adults and are associated with high morbidity, high mortality, and cost. About one out of six disability days among older persons are precipitated by falls, as are a large proportion of nursing home admissions. Falls have many underlying causes and identifiable risk factors that can be used in planning prevention measures and targeting the most appropriate intervention candidates. The most important fall risk factors include: muscle weakness, gait & balance disorders, prior falls, impaired vision, memory loss, functional impairment, and psychoactive medications. Environmental risk factors in the home and community also contribute to falls, and are potentially modifiable. The field of fall prevention has grown considerably in the past 15 years. Several intervention strategies have been shown in multiple controlled trials and meta-analyses to reduce risk of falls. The most powerful interventions include multi-factorial fall risk assessments with appropriate follow-up, targeted exercise programs, and environmental inspection and modification programs. Programs combining more than one of these strategies are even more effective. A clinical guideline developed by the American and British Geriatrics Societies assists health care professionals in using current evidence for assessing and reducing fall risk among older people. Newer studies are showing other innovative strategies that might further enhance effectiveness.

KS-4

Why do we walk the way we do? Mechanical determinants of the metabolic cost of healthy and pathological gait

M. Donelan

Kinesiology, Simon Fraser University, Burnaby, BC, Canada

Humans and other animals require metabolic energy to walk. Minimizing this metabolic cost appears to determine many aspects of how we walk (e.g. our preferred speed). While the importance of metabolic cost in determining our preferred walking biomechanics was recognized long ago, an understanding of why walking exacts a metabolic cost has remained elusive. Our approach has been to use mathematical models inspired by passive dynamic walking to make quantitative predictions regarding the determinants of metabolic cost and test these predictions using empirical experiments on humans and other animals. In this manner, we have identified two major biomechanical determinants of the metabolic cost of healthy human walking, step-to-step transition and limb swing costs, that account for about 90% of total metabolic cost at moderate speeds. There is a trade-off between these two costs—transition costs are minimized with short narrow steps while swing costs are minimized with long wide steps. Minimizing the sum of these two costs predicts measured preferred walking biomechanics remarkably well. Another intriguing determinant of the metabolic cost of walking is balance. Our theoretical and empirical results support the idea that lateral motion is passively unstable, is actively stabilized using medio-lateral foot placement, and this active stabilization exacts a modest metabolic cost (~10%). A new direction for our research is towards understanding the determinants of the metabolic cost of pathological gait. Dynamic walking models predict that symmetrical transitions, those during which the trailing leg performs an equal amount of positive work to replace the energy dissipated by the leading leg negative work, minimize the required mechanical work. Two common characteristics of pathological gait—be it from stroke, spinal cord injury or amputation—is left-right asymmetry and an elevation of the metabolic cost of gait. In subjects with hemiparesis due to stroke and in healthy subjects with simulated hemiparesis, we are currently testing the general hypothesis that the elevated metabolic cost of pathological gait is due to the increased muscle mechanical work required of asymmetrical step-to-step transitions. Our early empirical results are generally supportive of this hypothesis. It is our intention to use the results to guide the design of rehabilitation strategies, rehabilitation devices and assistive devices aimed at lowering metabolic cost and increasing patient mobility by improving transition symmetry.

KS-5

From Theory to Therapy: Implementing Innovations in Rehabilitation Technology

T. Weiss

University of Haifa, Haifa, Israel

Numerous technologies relevant to rehabilitation assessment and intervention have emerged over the past 50 years. Some have had an almost immediate and positive impact on clinical practice whereas the effect of others has been more obscure. For a variety of reasons, the implementation of technological innovations often lacks a solid theoretical foundation and/or evidence from clinical trials. The objective of this talk is to focus on how the application of the Gartner Group's "Technology Hype Cycle" may be applied to understanding the reasons why rehabilitation technologies succeed or fail in clinical settings. The Hype Cycle is a well-known tool that provides an overview of the status and progression of emerging technologies and trends in a broad range of applications (www4.gartner.com). It can be used as a means for understanding the dynamic process associated with the adoption and usage of new technologies. It is also an educational tool that helps explain why technologies should be adopted based on one's individual needs and goals, rather than on the current levels of hype and disillusionment in the marketplace. The Hype Cycle highlights the progression of an emerging technology from market over-enthusiasm through a period of disillusionment to an eventual understanding of the technology's relevance and role in a market or domain. When most new technologies initially appear in the market they appeal primarily to so-called "techies". Consider, for example, how few consumers were willing and able to buy an assemble-your-own, program-your-own personal computer in the mid-seventies when they first became available. Usually within five to ten years, the technology matures enough to become a useable, stand-alone tool ready to be adopted by brave "visionaries" who will buy it because they are fascinated by its current capabilities as well as its potential future applications. The technology at this point in time is still "cutting edge" in terms of cost, functionality and complexity. The pioneers who adopt the technology at this stage may succeed in gaining a competitive advantage, or they may become saddled with a white elephant that represents a drain on financial and time resources. The first owners of the Amega and Apple II personal computers in the early 1980s fit into this category. The third phase consists of a period of time during which the technology must prove that it provides a significant solution that can work reliably. Here we find that "pragmatists", also referred to as the "early majority of the main market", are willing to pay a relatively high price for the solution since the experience of the "techie" and "visionary" pioneers has suggested its effectiveness. In the field of aviation, this period of time lasted for over 30 years — the interlude between when the Wright brothers made their first airborne flight and the availability of the first commercial airline voyage. Examples are taken from the realm of rehabilitation technology to illustrate how the adoption and modification of various technologies has helped us to revolutionize various applications of technology to rehabilitation assessment and intervention. Example applications include online learning tools, simulated environments, quantitative handwriting evaluation tools, and assistive technology robotics and sonification techniques.

FS-1

Beyond Macpherson: Physiological mechanisms underlying postural responses

R. Nichols[1], P. Stapley[2], L. Ting[3] and J. Macpherson[4]

[1]Physiology, Emory University, Atlanta, Georgia, [2]Kinesiology, McGill University, Montreal, QC, Canada, [3]Biomedical Engineering, Emory University, Atlanta, GA, USA and [4]Neurological Sciences Institute, Oregon Health and Sciences University, Portland, OR, USA

Jane Macpherson's appreciation of both biomechanical and neurophysiological mechanisms underlying postural responses allowed her to generate an integrated and elegant body of work describing automatic postural responses in the awake, behaving cat. Her pioneering work not only allows us to better understand human postural control, but also lays the foundation for continuing research on the physiological mechanisms underlying postural control. This symposium will discuss research inspired by Jane Macpherson's work in the effort to understand postural control from an integrated systems physiology perspective, including the role of biomechanics, sensory feedback, and descending control. A unifying theme of Jane Macpherson's work was to understand the how muscles are activated to produce the proper forces for balance control. Lena Ting will discuss muscle synergies that may be used to control the forces produced during postural responses. She will demonstrate how biomechanical modeling can then be used to understand the organization and function of such muscle synergies. These muscle synergies may serve to simplify the descending control of muscles for postural responses. Paul Stapley will discuss the contributions of descending reticulospinal systems pathways in generating the postural responses to unexpected perturbations, and their possible role in activating muscle synergies. He will also discuss the contribution of sensory information and voluntary movements on postural responses, which may also contribute to muscle synergy selection. Richard Nichols will then discuss the patterns of sensory feedback that arise from multiple receptors in the limb, including muscle spindles, Golgi tendon organs, and cutaneous receptors, during whole limb perturbations and their role in postural responses. He will also discuss the role of musculoskeletal mechanics on force generation in postural control. We will allow ample time to discuss how the many pieces of the puzzle fit together to form a holistic view of the postural control mechanisms essential for basic motor control in both humans and animals.

FS-2

Functional imaging of axial motor control

B. Bloem[1], I. Toni[2], F. Mori[3] and J. Nielsen[4]

[1]Nijmegen Medical Center, Radboud University, Nijmegen, Netherlands, [2]Donders Center for Cognitive Neuroimaging, Radboud University, Nijmegen, Netherlands, [3]Medical Physiology, Yamaguchi University, Yamaguchi, Japan and [4]Medical Physiology, Copenhagen University, Copenhagen, Denmark

Perhaps one of the most exciting new areas in the field of gait and balance research has been the introduction of functional imaging techniques to unravel the neural substrate of axial motor control. In this mini-symposium, we will review the spectrum of neuroimaging techniques that have been used to functionally visualise the neural circuitries involved in generating gait and postural responses. The focus will be on the "higher-order" physiological processes involved in normal gait and balance, as well as the pathophysiological processes that are responsible for gait and balance disorders in neurological disorders. Speakers will cover a range of state-of-the-art techniques that provide complementary information about the neuronal machinery of axial motor control: functional magnetic resonance imaging, to identify functional circuits with high spatial resolution; positron-emission tomography (PET), to measure changes in regional cerebral blood flow or metabolism in brain areas with possible involvement in walking; and transcranial magnetic stimulation, whose ability to actively "perturb" the system allows to immediately test the functional relevance of neural circuitries. The presented lectures will review the technical feasibility and practical shortcomings of these techniques, and illustrate their application in gait and balance research based on recent scientific work. We will critically discuss recent and ongoing experiments involving both humans and subhuman primates. All presenters are recognised experts in their field. The session will conclude with a plenary discussion, with the aim to identify future challenges in this newly emerging field.

FS-3

Understanding the bilateral coordination of walking – impact on gait disturbances

J. Hausdorff[4], M. Plotnik[1], A. Nieuwboer[2] and S. Havlin[3]

[1]School of Health Professions, Tel-Aviv Sourasky Medical Center, Ramat Aviv, Israel, [2]Movement and Rehabilitation Sciences, Catholic University, Leuven, Belgium, [3]Physics, Bar Ilan University, Ramat Gan, Israel and [4]Medicine, Harvard Medical School, Boston, MA, USA

Normal gait is generally considered symmetrical and bilaterally coordinated. Recent findings suggest that there is an association between impairment in the ability to generate bilateral coordination and symmetry of gait. For example, patients with Parkinson's disease (PD) who suffer form freezing episodes exhibited asymmetrical gait and impaired synchronization of their left-right stepping as compared to PD patients who do not suffer from freezing. Interestingly, when challenged with a "dual task" while walking, patients with PD, increased their level of gait asymmetry and decreased the level of bilateral coordination of gait. In contrast, in healthy elderly control, dual tasking had no effect on symmetry or bilateral coordination. These finding raise interesting questions regarding the control of bilateral coordination. In this symposium, the speakers will review the different motor control levels where normal and impaired bilateral coordination of gait occur, will compare and contrast the bilateral coordination of upper extremity rhythmic movements to the coordination of walking and other lower extremity movements, and will present recent investigations and paradigms studying the role of bilateral coordination of gait and its changes in patients with gait disturbances.

FS-4

Attentional Mechanisms in Balance Control

A. Shumway-Cook[1], B. Maki[2], M. Redfern[3] and M. Woollacott[4]

[1]Rehabilitation Medicine, University of Washington, Seattle, WA, USA, [2]Center for Studies in Aging, University of Toronto, Toronto, ON, Canada, [3]Bioengineering and Otolaryngology, University of Pittsburgh, Pittsburgh, PA, USA and [4]Human Physiology, University of Oregon, Eugene, OR, USA

The control of balance has traditionally been thought to be largely automatic, requiring little or no attentional or other cognitive processing resources. However, recent research using a variety of secondary tasks to assess the attentional and cognitive requirements of balance has suggested that balance, in fact, requires information processing resources. It has thus been reported in many studies that when a postural and a secondary task are performed simultaneously, the performance on the postural task, the secondary task, or both, can decline. However, a small group of studies paradoxically have reported that concurrent performance of a cognitive task during standing actually reduces postural sway. This symposium will: 1) discuss issues related to balance performance in a variety of dual-task situations, with the aim of exploring this paradox; 2) explore other evidence (e.g. perturbation-evoked cortical potentials and gaze behavior) supporting cognitive contributions to the control of balance, 3) discuss potential models of postural control that incorporate cognitive function, and 4) address issues related to the use of dual-task paradigms in the rehabilitation of balance.

MO-special

Stance Phase Support – Don't Ignore the Musculoskeletal Anthropometrics

D.A. Winter

Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Dedication and Introduction: This paper is dedicated to my colleague and friend, Aftab Patla, who died in January of a brain tumor, prematurely ending a brilliant and exciting research and teaching career. During his 25 years at the University of Waterloo Aftab and I collaborated on many projects ranging from quiet standing to perturbed walking; I thank him for his insight, integrity and friendship. During stance phase of gait the extensor muscles of the stance limb prevent the vertical collapse of the total body. A total limb synergy was identified (Winter, 1980) that showed that the extensor muscles at all three joints collaborate to produce a support moment, M_s, whose profile mimics very closely the vertical ground reaction force, F_v. Also, when repeat intra and inter-subject trials are ensemble-averaged low variability of Ms is evident. This consistency was quantified (Winter, 1984) and for intra-subject averages was seen to be due to a high covariance between the hip and knee moments (89%) and between the knee and ankle moments (76%). The purpose of this paper is to determine the correlation between M_s and F_v and to determine the relative contribution of the uniarticulate versus the biarticulate muscles to M_s at all 3 joints to these covariance measures.

Methodology: Profiles from slow, natural and fast walking adults, as published in Winter (1991) were analyzed; M_s and F_v for slow (N=19), natural (N=19) and fast cadences (N=17) were correlated. The contribution of the muscles crossing the three joints was quantified by their individual moment generating capability (defined as the % physiological cross section of the muscle times its moment arm length -%PCA x MAL). The relative contribution of the uniarticulate vs the biarticulate muscles to the hip/knee and knee/ankle covariance was then estimated.

Results and Discussion: The correlation between M_s and F_v for natural cadence was 0.97, for fast walkers it was 0.95 and slow walkers it was 0.90. The %PCA x MAL measure for the flexor muscles at all 3 joints was 280 (uniarticulate = 122) and for extensors was 865 (uniarticulate = 658). Based on the scores of the individual muscles it was estimated that the biarticulate muscles crossing the knee and hip contribute only 31% of the 89% covariance and only 24% of the 76% covariance for the knee/ankle joint. The high covariance scores between M_s and F_v reinforces the fact that the reaction force, F_v, is caused by the total support limb synergy, M_s. The dominance of the uniarticulate muscles to the covariance is what keeps Ms consistent from stride-to-stride which is contrary to previous conclusions that this mechanism was essentially a by-product of the biarticulate muscles crossing these joints. Thus it was predicted that the only way the uniarticulate muscles could contribute to this instantaneously generated covariance is through a hard-wired neural network at the spinal level.

References:

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Sunday, July 15, 2007

Aging - Posture control

SO-1

Age-related differences in body-segment rotation magnitudes during gaze reorientation while standing or walking on a treadmill

M. Cinelli[1], A.E. Patla[2] and B.L. Stuart[2]

[1]*Cognitive and Linguistic Sciences, Brown University, Providence, RI, USA and* [2]*Kinesiology, University of Waterloo, Waterloo, ON, Canada*

Introduction: It is believed that with age, the function of the visual and vestibular systems decrease and lead to decreased head stabilization. This may cause individuals to become unstable and fall. The purpose of our study was to determine if a different strategy was used between young and older adults during visual reorientation and if this strategy promoted postural instability.

Methods: *Participants:* 8 young adults (23±1.5 yrs) and 10 community dwelling older adults (69±2.9 yrs). *Apparatus:* 19 LEDs arranged in a curvilinear fashion ranging from 0-90°, each separated by 5°. The LEDs extended from directly in front of the participants to their left with a 2m radius. *Protocol:* At the start of each trial the central LED (0°) was illuminated and when it extinguished another LED at one of the other 18 positions would simultaneously illuminate. There were two conditions: standing and walking on a treadmill (order of presentation was counter-balanced). Each LED randomly illuminated three times during both conditions.

Results: see figure

Conclusions: Older adults were unable to completely unlock their head from their trunk (i.e. shoulders & hips) when reorienting (i.e. larger rotation magnitudes). Increased trunk rotations by the older adults made the vestibulocollic reflex (VCR) more accountable for stabilizing the head. Since older adults have compromised vestibular systems, the VCR alone may not be able to prevent postural disturbances. The results from this study show that older adults are at a higher risk of falling because of their increase reliance on a reflex that has reduced sensitivity. The most efficient way to prevent postural disturbances is to reduce the amount of trunk rotations in order to allow both the VCR and cervicocollic reflex to work together as seen with the young adults.

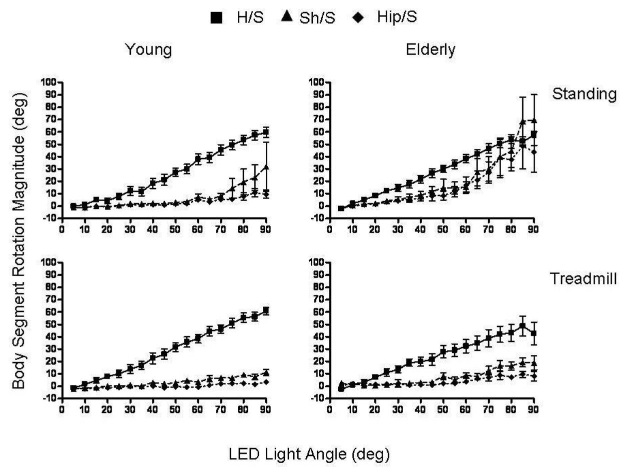


Figure 1- The average rotation magnitude for each body segment (H=head, Sh=shoulders, Hip) with respect to space (S) for both young and older adults during standing and treadmill walking conditions.

SO-2

Changes in mediolateral balance control in elderly fallers

I. Melzer[1], I. Kurz[1] and L. Oddsson[2]

[1]*Physical Therapy, Ben-Gurion University, Beer-Sheva, Israel and* [2]*NeuroMuscular Reaserch Center, Boston University, Boston, MA, USA*

Introduction: Fall-related injuries constitute a serious public health problem associated with human suffering as well as high costs for the society. Age-related deterioration of the balance control mechanisms due to aging can lead to balance impairment, may contribute to fall, limitations of mobility and eventually severe disability. Increased postural sway in older adults was objectively measured even during quiet standing. An effort was made in the present research study to understand age-related changes in postural control as reflected by Stabilogram-Diffusion (SD) parameter, their relation to falls and ability to identify elderly fallers. We also aimed to understand mechanisms contributing to age-related increases in postural sway in fallers.

Methods: One-hundred elderly male and female aged (65–91 years, mean age 78.4 ± 5.7), participated in a cross-sectional retrospective study in two self-care residential facilities. Twenty nine of the subjects reported fall in the past six months. Foot center-of-pressure (COP) displacements data collected during narrow base quiet-standing (heels and toes touching) and eyes closed while standing as still as possible. Independent T-test was performed comparing and characterizing traditional measures of COP displacement and SD analysis of elderly persons who reported loosing their balance and fall and non-fallers.

Results: Elderly fallers had significantly higher short-term diffusion coefficient and critical displacement in the mediolateral direction (see Table). No significant differences were found in long-term parameters. Mean Sway Area in the mediolateral, anterior-posterior directions and Mean Sway velocity were also higher in fallers.

Conclusions: Results indicate that elderly fallers are characterized by altered mediolateral short-term postural sway behavior. Such changes, as suggested by previous studies, may be related to increased lower limb muscle co-activation.

Stabilogram-Diffusion Parameters and Traditional Sway Parameters for fallers and non-fallers. Values are means(SEM).

	Fallers N=29	Non-Fallers N=69	P-value
Characteristics			
Gender (Female /Male)	9/20	18/51	NS
Age (years)	76.9(1.3)	78.9(0.66)	0.12
Stabilogram Diffusion Parameters			
Short-term Effectivediffusioncoefficients in mm2/sec (Dxs)	72.7(8.9)	50.2(3.5)	0.006
Long-term Effective diffusion coefficients in mm2/sec (Dxl)	2.9(0.5)	2.7(0.35)	0.7
Critical (Mean-Squared) Displacement in mm2 (Cdx,)	107.8(11.8)	77.1(5.6)	0.009
Critical (Mean-Squared) Time intervals in sec (Ctx)	0.85(0.28)	1.0(1.01)	0.23
Traditional Sway Parameters			
Average of ML-COP Range (mm)	43.9(2.5)	36.7(1.2)	0.004
Average of AP-COP Range (mm)	40(2.3)	34.3(1.1)	0.013
Average of Trial Mean Velocities (mm2/sec)	32.1(2.1)	27.3(1)	0.019
Mean Sway Area (mm2)	141.3(13.7)	103.2(5.4)	0.002

SO-3

Adult age-specific and age-general effects of cognitive load on the regularity of whole-body coordination in dual-tasked walking

J. Verrel, M. Lövdén, A.E. Pohlmeyer, S. Schaefer and U. Lindenberger

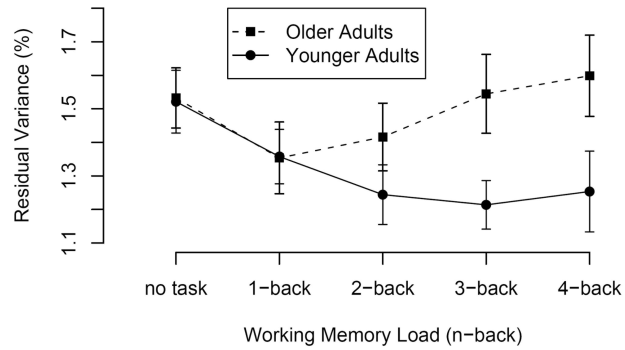
Center for Lifespan Psychology, Max-Planck-Institute for Human Development, Berlin, Germany

Introduction: When cognitive and sensorimotor tasks are performed simultaneously, older adults usually show greater dual-task costs than younger adults in either or both domains. We re-analysed kinematic data from a study on age-related interactions between working memory (WM) and walking using a novel measure of gait regularity based on principal component analysis (PCA) of whole-body motion.

Methods: Young (20-30 yrs) and old (70-80 yrs) participants (N=32 per group) performed a WM (n-back) task at different levels of difficulty (no task, 1-/2-/3-/4-back) while sitting or while walking on a treadmill at preferred speed. PCA was applied to the kinematic walking data collected during non-response intervals to determine dominant modes of individual gait patterns. Roughly, the first four components cover the main synergies occurring at the stride (e.g., arm and leg swing) and step frequency (e.g., vertical trunk movement), consistently accounting for over 90% of the variance. We devised residual variance (RV) as a measure of walking irregularity. Several step-related variability measures (SRVM; e.g., SD of step width) were also computed.

Results: While cognitive performance was not affected by the motor task, WM load did influence the regularity of gait patterns as assessed by RV (see figure). Both young and old adults showed an increase in regularity (drop in RV) from the no-task to the 1-back condition ($p<0.005$). Increasing WM-load led to differential effects for the two age groups (group-load interaction, $p<0.01$), with decreased regularity for the older participants. The absence of a group main effect improves interpretability of the interaction. Group main effects were present in SRVM, which otherwise showed similar but less pronounced effects or trends than RV.

Conclusions: The age-specific effects of increasing WM load are in line with previous results on aging-related increases in sensorimotor-cognitive interactions; the general gain in regularity from no-task to 1-back may be due to beneficial effects of external attentional focus. Additional work is underway to scrutinize the processes underlying our findings (e.g., the spatiotemporal structure of the residual pattern), the relation between RV and SRVM, and their significance for gait stability.



SO-4

The dynamics of multi-sensory re-weighting in healthy and fall-prone older adults

L.K. Allison[1], T. Kiemel[2] and J.J. Jeka[2]

[1]*Physical Therapy, East Carolina University, Greenville, NC, USA,* [2]*Kinesiology, University of Maryland, College Park, MD, USA and* [3]*Neuroscience and Cognitive Science, University of Maryland, College Park, MD, USA*

Introduction: Unexplained falls in older adults are thought to arise from subtle deficits in multiple postural control system components. One commonly proposed deficit is a decline in the adaptive use of changing sensory inputs for estimating body dynamics, i.e., multi-sensory re-weighting. Recent work suggests that adaptation to amplitude changes in visual and touch stimuli is intact in healthy and fall-prone older adults without peripheral sensory loss. However, the rate of adaptation may be slowed with age; a slower adaptation rate might increase fall-risk. The purpose of this study was to characterize differences in the time required to adaptively re-weight visual information following a sudden change in visual motion amplitude in healthy young, healthy older, and fall-prone older adults.

Methods: Three groups of subjects (healthy young, healthy elderly, fall-prone elderly) were exposed to two visual motion conditions in which the amplitude of visual motion stimuli switched from low-to-high or high-to-low. Postural sway responses were analyzed (gain, phase, position variability and velocity variability). We compared absolute levels of gain at, and adaptive gain changes across, selected time intervals and between groups. Changes in gain over time were analyzed to obtain comparative prolonged rates of change before and after each amplitude switch, and rapid rates of change at each switch.

Results: Absolute levels of gain, pre-and post-switch, were consistently higher in both older adult groups than in the young, when the stimulus amplitude was high. Gains were frequently higher in the fall-prone versus healthy older and young adults when the stimulus amplitude was low. For all three groups, adaptive sensory re-weighting was reflected by gain changes following stimulus motion amplitude changes. All three groups demonstrated equally rapid re-weighting at the time of the amplitude

switch. Between-group differences were apparent in the prolonged changes in gain. Compared to young adults who usually did not re-weight further after the initial rapid adaptation, both older adult groups demonstrated continued gradual changes in gain over time periods of 105 seconds. When the stimulus amplitude was high, both older adult groups demonstrated slower prolonged adaptation rates than the young. Rates of prolonged adaptation were not different between the older groups and the young when the stimulus amplitude was low.
Conclusions: Rapid re-weighting when the stimulus amplitude suddenly increases is necessary to prevent instability. All three groups demonstrated functionally adaptive responses. However, down-weighting to high-amplitude stimuli is slower and to a lesser extent in healthy and fall-prone older adults compared to young adults. With low-amplitude stimuli, fall-prone older adults continued to have the highest absolute levels of gain and slowest rates of prolonged change compared to healthy older and young adults.

SO-5

Delays in voluntary step initiation are related to increased volume of white matter hyperintensities in older adults

P.J. Sparto[1], H.J. Aizenstein[2], J.M. VanSwearingen[1], C. Rosano[3], J.M. Furman[4], M.S. Redfern[5] and S.A. Studenski[6]

[1]Physical Therapy, University of Pittsburgh, Pittsburgh, PA, USA, [2]Psychiatry, University of Pittsburgh, Pittsburgh, PA, USA, [3]Epidemiology, University of Pittsburgh, Pittsburgh, PA, USA, [4]Otolaryngology, University of Pittsburgh, Pittsburgh, PA, USA, [5]Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA and [6]Medicine, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: An increased volume of white matter hyperintensities (WMH) on MRI has been associated with mobility impairments in older adults. Damage in white matter tracts may disrupt the timing within circuits that are important for postural control. The objective of this preliminary study was to investigate the relationship between the WMH and delays in voluntary step initiation.
Methods: Eight subjects (4 female) aged 75-85 y participated. WMH quantification within 20 white matter tracts was computed using an automated extraction method (Wu et al., 2006). The volume of WMH in the corticospinal tracts and anterior thalamic radiations were summed. Subjects performed a voluntary stepping task that included two simple reaction time (SRT) trials and one choice reaction time (CRT) trial. SRT trials required subjects to step as quickly as possible with the right foot from a symmetric standing position to a single target position located either 10 (R1) or 18 (R2) inches to the right in response to an auditory stimulus. For the CRT trial, subjects stepped as quickly as possible to location R1 or R2 when a 560 Hz or 980 Hz tone was randomly presented. The time from the stimulus onset to the liftoff of the right foot was computed for each stimulus. The mean liftoff time for each step location was computed for each trial. The difference between the CRT and comparable SRT liftoff times was computed to gauge the change in central processing time required for recognizing the tone and planning the appropriate step size. Pearson's correlation coefficients were computed between the log of the volume of WMH and liftoff times.
Results: The volume of WMH in the projection tracts ranged from 0.1 to 3.1% of the total brain volume. The mean liftoff time was at least 141 ms greater for the CRT steps compared with the SRT steps to the same location (Table, $p < 0.02$), reflecting increased central processing times. Increases in WMH were significantly associated with larger liftoff times during both SRT and CRT for both target locations (Table). The correlation between WMH and the difference in liftoff times between SRT and CRT ranged from 0.52 to 0.64.
Conclusions: These data suggest that increased volume of white matter hyperintensities in projection tracts is associated with greater central processing time during voluntary step initiation. This study highlights a possible mechanism that can help to explain how damage to white matter tracts reduces mobility in older adults.

Correlation between volume of WMH and liftoff times

Step Location	Mean (s.d.) Liftoff Time	Pearson's Correlation between log(WMH) and Liftoff Time	p-value
R1:SRT	577 (127)	0.73	0.04
R1:CRT	728 (102)	0.79	0.02
R1:CRT-SRT	151 (167)	0.52	0.19
R2:SRT	554 (194)	0.89	0.003
R2:CRT	696 (77)	0.87	0.005
R2:CRT-SRT	141 (121)	0.64	0.09

SO-6

Force platform balance measures as predictors of risk for falling indoors and outdoors in community dwelling 63 to76-year-old women

S.S. Pajala[1], P. Era[2], M. Koskenvuo[3], J. Kaprio[4], T. Törmäkangas[1] and T. Rantanen[1]

[1]Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland, [2]Finnish Brain Research and Rehabilitation Center Neuron, Kuopio, Finland, [3]Department of Public Health, University of Helsinki, Helsinki, Finland and [4]Department of Mental Health and Alcohol Research, National Public Health Institute, Helsinki, Finland

Introduction: Older persons not able to maintain balance while standing have severe balance impairment and are at an increased risk of falls. However, whether more subtle changes in balance control typically measured as an increase in the center of pressure (COP) movement using force platform technology predict falls has not been confirmed in population-based studies. We assessed whether force platform balance tests predict the risk for falling indoors, outdoors and overall risk for falls among older people with no manifest deficiency in standing balance.
Methods: This study was conducted as a part of Finnish Twins Study on Aging. Participants were 434 community living women aged 63 to 76 years. COP was measured in six progressively more difficult stances on a force platform. Following the balance tests, 429 participants took part to 12-month fall surveillance carried out using monthly fall calendars. The incidence rate ratios (IRR) with 95% confidence intervals (CI) were obtained from negative binomial regression models.
Results: During the follow-up, 58 participants reported one or more indoor falls and 132 people reported outdoor falls but no indoor falls while 239 people reported no falls. For all balance tests performed, the highest risk of indoor falls was consistently

observed among those in the highest third of COP movement. COP movement during balance tests did not predict risk for falls outdoors or falls irrespective of location.
Conclusions: The present results suggest that force platform balance tests may identify older people with subtle changes in balance control who are at increased risk of indoor falls. As falling outdoors depend also upon situational factors, other than COP movement measures are needed to predict risk for outdoor falls.

Cognitive Influences on Posture and Locomotion

SO-7

Influence of postural anxiety on the cortical response associated with postural reactions to predictable and unpredictable trunk perturbations

A.L. Adkin[1], A.D. Campbell[2], R. Chua[2] and M.G. Carpenter[2]

[1]Faculty of Applied Health Sciences, Brock University, St. Catharines, ON, Canada and [2]School of Human Kinetics, University of British Columbia, Vancouver, BC, Canada

Introduction: The involvement of the cortex in postural reactions remains unclear. Previous work has revealed significant differences in the cortical response associated with postural reactions to unpredictable compared to predictable perturbations (Adkin et al. Exp Brain Res 2006; 172: 85-93). Unpredictable perturbations evoked a large negative cortical potential (N1) that was not detectable in predictable perturbations. Postural anxiety has been shown to contribute to changes in postural reactions (Carpenter et al. J Neurophysiol 2004; 92: 3255-65) and may play a role in modifying the cortical response associated with postural reactions to predictable and unpredictable perturbations. The goal of the present study was to investigate the effects of postural anxiety on the cortical response evoked by predictable and unpredictable perturbations to upright stance.
Methods: Nine healthy young adults were exposed to a series of 50 predictable and 50 unpredictable trunk perturbations when standing at ground level (low postural anxiety) or at the edge of a platform located 3.0-m above ground level (high postural anxiety). Unpredictable perturbations were of unknown timing and direction (forward, backward, left, or right) whereas predictable perturbations were of known timing (perturbation onset cued by an auditory tone) and direction (always forward). Only responses to forward perturbations were compared in this study. Peak and time to peak of the cortical response (N1 at CZ) and leg muscle activity were calculated. Self-reports of perceptions of confidence, anxiety and stability were obtained.
Results: The results of this study showed that postural anxiety modified the cortical response associated with unpredictable trunk perturbations. A N1 was evoked by unpredictable perturbations, with the N1 significantly more negative (35.4%) when responding in the high compared to low postural anxiety condition ($p<0.05$). The change in magnitude of the N1 from low to high postural anxiety was largest for participants reporting greater decreases in balance confidence or greater increases in balance anxiety from low to high postural anxiety ($p<0.05$). The results of this study also showed that postural anxiety did not modify the cortical response associated with predictable perturbations. There was no noticeable N1 response to predictable perturbations in either the low or high postural anxiety condition. Significant compensatory responses were observed in all conditions.
Conclusions: The results demonstrated that postural anxiety augments the large negative potential evoked by postural reactions to unpredictable perturbations. This augmented response may represent facilitation of the sensory representation of the balance disturbance in response to heightened anxiety. This study supported by grants from NSERC (ALA, RC, and MGC).

SO-8

The effect of dual and multi-tasking on gait performance in a cohort of community dwelling elderly people

C.J. Bula[1], E. Martin[1], K. Aminian[2], S. Rochat[1], B. Najafi[2], V. Besson[2], M. Thomi[1], A. Vacheron[1], A. Karmaniola[4], B. Carolina[4], C. Piot-Ziegler[3] and B. Santos-Eggimann[4]

[1]Geriatrics, CHUV, Lausanne, Switzerland, [2]LMAM, Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland, [3]Health Psychology Unit, University of Lausanne, Lausanne, Switzerland and [4]Institute for Social & Preventive Medicine, University of Lausanne, Lausanne, Switzerland

Introduction: This study aims to determine gait performance in a large sample of well-functioning, community-dwelling elderly persons and compare the effect of three different dual- and multi-tasking conditions on gait parameters.
Methods: Subjects are community-dwelling elderly persons enrolled in the "Lc65+" cohort that investigates the determinants of frailty in a representative sample of the population aged 65 to 70 years in the city of Lausanne, Switzerland (N=1565). Extensive data were collected on demographics, socio-economic, functional, cognitive, affective as well as health status. Gait performance and fear of falling were assessed during baseline assessment in a sub-sample. Gait parameters were measured over a 20m walk at preferred gait speed, using the Physilog system, with participants wearing their own shoes. Measures were performed under 4 conditions: 1) Single task: normal walk; 2)Dual task #1: walking while counting backward aloud; 3) Dual task #2: walking while carrying a glass of water; 4) Multitask: walking while counting backward aloud and carrying a glass of water.
Results: Participants' (N=864) mean age was 68.0±1.4 years, 55.1% were women, 31.3% living alone. Full independence in basic and instrumental activities of daily living were reported by 92.3% and 88.9%, respectively, and cognitive performance at Folstein's MMSE was normal (score >=24) in 98.0%. One or more fall in the previous year was reported by 13.2%. Compared to the single task condition, each dual- and multi-task conditions significantly affected gait performance (Table), with decreased gait speed and stride length, increased double support, and increased gait variability. Comparisons among the different dual and multitask conditions were also all statistically significant (all $P<.001$), multitasking resulting in the largest modifications, while counting backward (dual task #1) had a significantly higher impact on gait than carrying a glass of water (dual task #2).

Conclusions: Overall, these results show that, even in a population of relatively young elderly persons with a high level of physical and cognitive performance, gait performance is significantly altered in dual- and multitask conditions. These results also confirm the hypothesis that a task with higher cognitive (especially executive) demand has stronger interference with gait.

Comparisons of gait performance under different conditions (N=864).

Variables	Single task	Dual task #1	Dual task #2	Multitask	P-value
Gait speed (m/sec)	1.13±0.16	0.99±0.19	1.07±0.17	0.95±0.19	<.001
Gait speed CV (%)	3.5±2.4	6.2±4.3	3.8±2.8	6.0±4.2	<.001
Double support (%)	9.53±2.58	10.56±2.66	9.84±2.96	10.81±3.10	<.001
Double support CV (%)	14.9±12.9	16.0±14.1	16.1±13.7	15.8±12.9	.009
Stride length (m)	1.21±0.14	1.18±0.15	1.16±0.15	1.14±0.15	<.001
Stride length CV (%)	2.4±1.9	3.3±2.4	2.5±1.8	3.1±2.1	<.001

P value from ANOVA (subject's effect taken into account).

CV : coefficient of variation.

SO-9

Age differences in walking and judging during different phases of gait

S.A. Fraser[1], K.Z. Li[1], V.B. Penhune[1], R.G. DeMont[2], M.C. Hendry[1], G. Abbud[2] and K. Hamati[1]

[1]Psychology, Concordia University, Montreal, QC, Canada and [2]Exercise Science, Concordia University, Montreal, QC, Canada

Introduction: Two experiments were carried out to (i) evaluate age and divided attention effects during different phases of the gait cycle, and (ii) to explore the limits of compensatory muscle activity during dual task walking. To address our first goal, we compared single and dual task treadmill walking and auditory word judgments between groups, splitting the gait cycle into preactivation (150 ms prior to heel strike) and stance (heel strike to toe-off) phases. To address our second goal, we varied the cognitive demands across experiments (2- vs. 3-choice responses in E1 and E2, respectively).
Methods: In both experiments, healthy young (18-35) and older (60-80) adults completed counterbalanced blocks of walking, judging, and dual task trials. For the cognitive task, participants judged the animacy (E1) or size (E2) of each concrete noun. Words were presented at irregular intervals. Vocal reaction times and accuracy were measured. For the walking task, participants first set their own pace (self-rated as moderate) and walked at 0 degrees (E1) or at -15 degrees (E1, E2) downhill. Surface EMG activity was recorded for eight muscle groups of the dominant leg. Balance status was assessed with the Sharpened Romberg Test. For both studies, dual task costs (DTCs) were calculated as the difference between single and dual task performance in each domain (cognitive – reaction time; motor - EMG). For the EMG data, DTCs were considered separately for each muscle group.
Results: In E1, cognitive DTCs for both age groups were negative, indicating dual task facilitation rather than cost. Across all participants, planned comparisons of stance phase single vs. dual task activity revealed significant or marginally significant DTCs for six muscle groups. When the stance data were split by age group, DTCs in four muscle groups were significantly greater than zero for the OA. Balance status was positively correlated with stance DTCs in five muscle groups, suggesting that OA with poor balance exhibited compensatory muscle activity in the dual task condition, especially when walking downhill. The preactivation DTCs revealed no significant interactions or main effects. To date, E2 indicates that the cognitive demands of making 3-choice judgments are greater than when making 2-choice judgments.
Conclusions: Our results underscore the importance of attention during the stance phase when the maintenance of balance is vital. The results also suggest a continuum of dual task effects such that under easy to moderate dual task conditions, it is possible to compensate for poor balance due to available reserve capacity. In contrast, under more challenging dual task conditions, insufficient reserve capacity may alter participants' ability to prioritize the allocation of their attention.

SO-10

Trace conditioning of automatic postural reflexes

A. Campbell, C. Dakin and M.G. Carpenter

School of Human Kinetics, University of British Columbia, Vancouver, BC, Canada

Introduction: Classical conditioning has been used to elicit specific muscular responses to numerous forms of external stimuli. Trace conditioning, whereby the conditioned stimulus (CS) is separated from the unconditioned stimulus (US) by a short-latency 'off-stimulus' period, has been shown to develop robust associations in initiating the eye-blink reflex to an auditory tone [1]. Automatic postural reflexes (APRs) are thought to be longer-loop reflexes that elicit stereotypical postural responses to unexpected balance perturbations. The aim of the present research project is to determine whether a conditioned auditory stimulus can be used to elicit an APR in the absence of any visual, somato-sensory, or vestibular stimuli.
Methods: Nine healthy young adults (age range: 22-26 years) volunteered for this study. With their eyes closed, subjects experienced 17 toe-up rotational perturbations (US) of 7.5° at 60°/sec presented with a random 5-60s inter-stimulus interval. Rotational perturbations were coupled with a preceding 200ms auditory tone (CS) ending 100ms before the onset of the US. After the 17 conditioning trials, subjects were exposed to a final trial consisting of only the CS (i.e. tone without a subsequent perturbation). Surface electromyography (EMG) was recorded unilaterally in the tibialis anterior (TA) and the soleous (SOL) muscles. Onset latencies were identified as the time when muscle activity surpassed two standard deviations above mean background activity calculated 100ms prior to the CS. Muscle onsets were referenced to the start of platform movements specific to each trial.
Results: After the series of CS-US conditioning trials, seven subjects (78%) displayed clear TA responses to the presentation of the CS-only trials. Mean onset latencies of TA during conditioning trials (136.38±55.53ms) were not significantly different than latencies of TA onsets during CS-only trials [$t(6)=1.88$, $p>0.10$, non-directional]. Interestingly, although clear stretch reflex activity was evident in SOL during conditioning trials, no stretch reflex activity was observed in SOL when the CS was presented alone.
Conclusions: The results from this project demonstrate the feasibility of using trace conditioning to elicit an APR from an auditory stimulus. This conditioning response is evident in subjects'

TA reaction to the auditory tone in the absence of physical perturbation. We believe that because TA response latencies are similar to those seen during balance perturbing trials, supraspinal influences may have a role in reflexive balance response initiation in the absence of a proprioceptive mechanism. Furthermore, absent SOL responses to CS-only presentations suggests that lower leg stretch reflexes are not a contributing factor in triggering APRs. Acknowledgements: NSERC support to M.G. Carpenter References: [1] Steinmetz JE (2000) Brain substrates of classical eyeblink conditioning: a highly localized but also distributed system. Behav Brain Res 110:13-24

SO-11

Attention influences sensory integration during standing posture

M. Redfern[1], M. Muller[2] and J. Jennings[2]

[1]Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA and [2]Psychology, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: Recent studies have suggested that attention influences the sensory integration process in postural control. The objective of this study was to investigate the influence of attention on sensory integration during standing postural control. Specifically, we hypothesized that visual channels used in postural control would be enhanced, while auditory channels would not. We tested this hypothesis in young and older adults.

Methods: Twenty two young (25.6+/- 3.8 yrs)and 12 older (74.5+/- 4.7 yrs) subjects participated. Two tasks were included: Auditory Choice Reaction Time (ACRT) and a Visual Choice Reaction Time Task (VCRT). The ACRT used two tone amplitudes as the stimuli. THE VCRT used two brightness levels of an LED. Each stimulus was presented for 250 ms. The response was a button push of the right or left hand, depending upon the stimulus. The tasks were performed while standing on an Equitest device (Neurcom, Inc). The 6 conditions combine three visual and two floor conditions. Visual conditions were: 1) Eyes Open-Fixed Scene (EO), 2) In the dark (DARK), and 3) sway-referenced vision (SRV). Floor conditions were: 1) Fixed Floor (FIX) and 2) sway-referenced floor (SRF). Control conditions were included: Seated RT tasks in each visual condition, and standing in each postural condition without an RT task. Measures of performance were RTs and sway (RMS of the COP). The RTs were normalized by subtracting the seated RTs within visual condition. Sway RMS was normalized by subtracting the values obtained without the IP task. The normalized RT (nRT) and the normalized RMS (nRMS) were analyzed.

Results: Analysis of the nRTs was a split-plot design ANOVA with primary variables Group (young, older), Task (ACRT, VCRT), Floor (FIX, SRF), Scene (EO, DARK, SRV) and all interactions. Significant ($p<.05$) effects were Task (Auditory > Visual), Floor (SRF>Fixed), Scene (VSR>EO>Dark), Task*Floor, and Task*Scene. No age group effect on the nRTs was found. Post-hoc tests indicated no significant difference in nRT between EO and VSR for the VCRT task, but there was a significant difference for the ACRT task. Analysis of the nRMS used the same ANOVA analysis as in the RT analysis. Significant effects were Group, Scene, Floor, Group*Floor. Older adults had reduced nRMS, particularly in the SRF condition. The EO condition had reduced nRMS compared to the other two Scene conditions.

Conclusions: Postural conditions had differential effects on nRTs, with auditory responses being increased more than visual responses. In addition, complex sensory integration conditions (SRF and VSR) had a greater impact on auditory RT as well. Interestingly, this effect was not influenced by age. Based on these results, we propose that attention during standing enhances sensory channels that are important for postural control at the expense of senses that are not.

SO-12

Cognitive and motor mediators of the changes in gait stability during dual tasking in healthy older adults: single task performance does not necessarily predict dual task

J.M. Hausdorff[4], G. Yogev[2], T. Herman[2], M. Brozgol[2], N. Inbar-Borowsky[2], L. Gruendlinger[2] and N. Giladi[1]

[1]Department of Neurology, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel, [2]Laboratory for Gait & Neurodynamics, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel, [3]Physical therapy department, Sackler School of Medicine, Tel-Aviv, Israel and [4]Division on Aging, Harvard Medical School, Boston, MA, USA

Introduction: Dual tasking may reduce swing time, a measure reflecting balance during gait, and increase swing time variability, a measure of consistency. We tested the hypothesis that in older adults these changes are related to cognitive function, motor function, and single task, usual walking abilities.

Methods: 172 community-living older adults (mean: 76.5+/-4.6 yrs; 62% women) participating in a prospective study of gait and cognitive function were evaluated. Subjects walked independently and were free of neurodegenerative disease, dementia, and pathologies likely to directly affect gait or cognitive function. Subjects walked while wearing footswitches for 2 minutes under 4 conditions (random order): usual, single task walking, while subtracting serial 3's, while subtracting 7's, and while phoneme monitoring (PM). The Berg Balance Test (BBT) and the Dynamic Gait Index (DGI) were also used. Memory, executive function (EF), attention, and visual spatial abilities were quantified using a neuropsychological battery. The dual tasking decrement of the average % swing time (DTD-A) and swing time variability (DTD-V) were ranked (each in turn); subjects in the top 3rd and bottom 3rd were compared. To correct for multiple comparisons, a p-value of 0.01 (two-sided) was used.

Results: 1) Overall, BBT (54.0+/-2.4) and DGI (22.9+/-1.5) scores were near perfect. The DTD-A (e.g., mean decrement<1%) and DTD-V (e.g., mean changes<1%) were small, but significant ($p<0.009$) for all 3 cognitive tasks. 2) For each of the 3 dual tasks, cognitive function measures were not different in subjects with low vs. high DTD-A, but subjects with a low DTD-V had higher (better) EF ($p<0.009$). Subjects with a low DTD-V in the PM dual task also had better scores on the other cognitive domains ($p<0.008$). 3) Subjects with a low DTD-V had higher BBT and DGI scores, compared to those with a high DTD-V (e.g., $p<0.004$ PM task), but these scores were not related to the DTD-A. 4) Single task walking swing time and swing time variability were not related to the DTD-A or to the DTD-V.

Conclusions: Among relatively healthy older adults, usual walking does not predict the effects of dual tasking and thus, may not be optimal for fall risk identification. The decreased swing time during a dual task is also apparently not strongly related to cognitive function or to functional measures of gait or balance. Conversely, the dual tasking effect on the consistency of the stepping pattern (e.g., DTD-V) is associated with balance (e.g., BBT), EF, and, other cognitive domains as well, at least for certain dual tasks (e.g., PM). These findings underscore the differences in the factors required for "balance" during walking and those needed to maintain a consistent and steady gait. Further, they also demonstrate that to meet the everyday challenges of dual tasking, a consistent gait pattern apparently depends on intact gait, balance and executive function.

Rehabilitation and Training: Stroke

SO-13

The impact of increasing plantarflexors and hip flexors muscle strength on the level of effort during gait in individuals with hemiparesis

M. Marie-Helene[1], N. Sylvie[2], G. Denis[2], B. Daniel[2], C. Pauline[2] and C. Susan[3]

[1]École de réadaptation, Université de Montréal, Montréal, QC, Canada, [2]Institut de réadaptation de Montréal, CRIR, Montréal, QC, Canada and [3]Hôpital de réadaptation Lindsay, Montréal, QC, Canada

Introduction: Strengthening programs represent an effective way to reduce weakness of the affected lower-limb muscles following a stroke but their impact on gait speed is inconsistent. Moreover, the mechanism underlying the impact of strength gains on hemiparetic gait pattern has been scarcely studied. Thus, the aim of this study was to assess the impact of strength gains of the affected plantarflexors and hip flexors on gait speed and on the related levels of effort during gait.
Methods: Twenty-four chronic hemiparetic participants (17 males and seven females; mean age: 57.3 (SD 15.5) years), who presented a 10% or more strength gain at either the plantarflexors or hip flexors following an isokinetic strengthening program, participated in this study. The levels of effort and self-selected and maximal gait speeds were assessed before and after the training program. The Muscular Utilization Ratio (MUR), which compares the net moment used during gait to the maximal moment of a muscle group, was used to estimate the level of effort of the plantarflexors and the hip flexors. Participants underwent a biomechanical gait analysis at self-selected and maximal speeds and a maximal strength testing in plantar flexion and hip flexion with a Biodex dynamometric system. The gait speeds and the peak MUR values of the affected and unaffected sides were compared before and after the training program. ANOVAs were used to assess the effect of strength gains on peak MUR values and gait speeds and to evaluate the effect of side on peak MUR values, along with effect sizes. The Pearson product moment correlation coefficients allowed examining the association between the changes in strength and peak MUR values as well as gait speeds.
Results: With strength gain, a significant reduction in the peak MUR ($p=0.008$) was observed. At self-selected speed, a 17% (effect size 0.6) and a 15% (effect size of 0.5) mean decrease for the plantarflexors and hip flexors peak MUR was noted, respectively while at maximal speed, the corresponding mean decline was 18% (effect size 0.5) and 9% (effect size 0.2). A significant, albeit small, increase in self-selected and maximal gait speeds (effect sizes 0.2; $p<0.05$) was also found. In general, no significant difference was observed in the peak MUR values between sides and significant negative associations ($-0.18< r <-0.82$) were observed between the changes in strength and peak MUR but no association was noted between the changes in gait speed and peak MUR.
Conclusions: As estimated by the MUR, with strength gain, the hemiparetic participants decreased significantly their levels of effort during walking, instead of increasing importantly their gait speed. The increase in strength did not affect the levels of effort on the unaffected side. This study suggests that strengthening the weakened affected muscles could bring other benefits than increasing gait speed such as reducing the levels of effort during hemiparetic gait.

SO-14

Tai Chi improves standing balance in people with chronic stroke

S. Au-Yeung[1], C. Hui-Chan[2] and J. Tang[3]

[1]Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China, [2]Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China and [3]Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China

Introduction: Our previous studies demonstrated that Tai Chi significantly improved balance performance in older people - to a level even comparable to that of young healthy subjects. Since people with stroke experience problems with balance and mobility, we embarked on the present study to investigate the effectiveness of modified Tai Chi (TC) on balance and mobility in people with chronic stroke.
Methods: 114 subjects with a history of stroke 6 months or longer were examined. The inclusion criteria were: ability to walk independently with or without aids, Mini-Mental State Examination score ≥ 23, no severe perceptual impairment, no previous TC training, and not participating in structured rehabilitation programme during the study. Subjects were randomly assigned to a Tai Chi (n=59) or a control (n=55) group given general conditioning exercises, with ≥ 3 hours of practice each week for 12 consecutive weeks. Two main outcome measures were recorded at 4 time intervals: baseline, week 6 (interim) and week 12 at programme completion, with follow-up at week 18. (1) Postural stability was measured by means of the limits of stability (LOS) in self-initiated movement of the centre of gravity (COG), and by equilibrium ratios of the sensory organization test (SOT) evaluated with the EquitestTM (NeuroCom, USA). (2) Functional mobility was measured by the timed-up-and-go (TUG) test measured by a blind assessor. Mixed model repeated measures ANOVA was used to examine within-group and between group differences.

Results: For the LOS test, the TC group showed significantly greater excursion amplitude in moving the COG to 4 directions (forward, backward, affected and non-affected side, P<0.000), and faster reaction time in moving towards the non-affected side (P<0.01) than the control group. These improvements reached significant between-group differences starting from week 6 and were maintained even at week 18 follow-up. For the SOT test, the TC group showed significant within-group improvement in the vestibular equilibrium ratio when they had to maintain standing equilibrium against perturbations that challenged mainly the vestibular function. The control group showed negligible within-group changes over time for all the outcome measures. Despite improvement in balance performance, functional mobility as assessed by the TUG score did not reach significant difference between the two groups.
Conclusions: In contrast to general conditioning exercises, 12 weeks of modified TC produced significantly better and lasting improvements in the amplitude and reaction time of self-perturbed COG movements in people with chronic stroke. Such improvements are probably specific to the TC training not embedded in the general conditioning programme.

SO-15

Comparison of treadmill and overground walking at self-selected speed in persons with post-stroke hemiparesis

S.A. Kautz[1], C.K. Balasubramanian[3], M.G. Bowden[1] and R.R. Neptune[4]

[1]VA Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA, [2]Physical Therapy, University of Florida, Gaineville, FL, USA, [3]Rehabilitation Sciences Doctoral Program, University of Florida, Gaineville, FL, USA and [4]Mechanical Engineering, The University of Texas, Austin, TX, USA

Introduction: The availability of instrumented treadmills has facilitated the capture of complete kinesiological walking data sets during locomotion. Specific differences have been documented for walking on a treadmill versus overground in healthy persons as well as in persons with hemiparesis post-stroke. However, the relevance of these differences is often unclear, depending to a large extent upon the question being asked. The purpose of this study was to compare EMG, spatiotemporal and kinematic data between treadmill and overground walking at self-selected speed (SS) in persons with post-stroke hemiparesis. Specifically, we hypothesized that SS walking on a treadmill will show some differences compared to overground (most notably walking slower and having a shorter stride length), but that the main impairments that characterize hemiparetic walking (EMG, spatiotemporal and kinematic measures) will remain unchanged between the two walking modes.
Methods: Fifteen hemiparetic subjects walked for 3 trials at their SS speed over an instrumented walkway (GAITRite) and for 2 trials of 30 sec on an instrumented treadmill (Tecmachine). Sixteen channels of EMG were used to record bilateral muscle activity. Sets of marker clusters on rigid bases and critical markers, both virtual and real, were recorded using a 12-camera motion capture system (Vicon) to collect bilateral 3D kinematics. Custom MATLAB programs and Vicon plugins were used to perform the data analyses. Paired t-tests were used to compare the different measures in the two walking modes.
Results: SS on the treadmill was slower (0.34 vs 0.51 m/s, p=0.002) and the stride length was reduced (0.47 vs 0.82 m, p< 0.0001). However, there was no difference in the step length asymmetry between conditions. All differences in kinematics (reduced peak in hip extension, knee flexion and ankle dorsiflexion, p<0.05) were consistent with expectations based on the slower speed and reduced stride length of treadmill walking. Changes in paretic leg EMG timing were present in some muscles, with the most consistent finding being increased percent activity in the first double support phase (which was mostly explained by the increased percent of the gait cycle spent in this phase during the slower treadmill walking).
Conclusions: Despite differences in some variables between the two modes of walking, little evidence was found to suggest that impairments observed in SS treadmill walking would be different than impairments in SS overground walking. Thus, we propose that SS treadmill walking can serve as a valid surrogate for SS overground walking when analyzing paretic leg impairments in persons with post-stroke hemiparesis. Data collection on an instrumented treadmill allows many advantages, including collection of a large number of consecutive bilateral steady-state steps, which is not possible with current overground data collection protocols. **Acknowledgements:** Funding was provided by NIH grant R01 HD46820.

SO-16

Learning postural tasks in hemiparetic patients with lesions of left versus right hemisphere

M. Ioffe[2], L. Chernikova[1], R. Umarova[1], N. Katsuba[1] and M. Kulikov[2]

[1]Institute of Neurology of RAMS, Moscow, Russian Federation and [2]Institute of Higher Nervous Activity & Neurophysiology, Moscow, Russian Federation

Introduction: There is a number of studies concerning difference of postural control following left or right hemisphere lesions [1- 4]. The present work deals with learning postural tasks after lesions of left versus right hemisphere.
Methods: 32 patients (20 men, mean age 53, 3+13, 3 years) with hemiparesis after ischemic stroke in the middle cerebral artery territory (20 with a left and 12 with a right hemispheric lesion) were investigated. The patients with hemineglect were excluded from the study. The subjects stood on a force platform and were trained to change the position of the center of pressure (COP) presented as a cursor on a monitor screen in front of the patient. Subjects were instructed to align the COP with the target and then move the target by shifting the COP in the indicated direction. Two different tasks were used. In “Balls”, the target (a ball) position varied randomly, so the subject learned a general strategy of voluntary COP control. In “Bricks”, the subject had to always move the target in a single direction (downward) from the top to the bottom of the screen, so that a precise postural coordination had to be learned. The training consisted of 10 sessions for each task. The number of correctly performed trials for a session (2 min for each task) was scored.
Results: The voluntary control of the COP position was initially impaired in all groups of patients in both tasks. In”Balls”, there were no differences in the time course of learning and in

the final level of the task performance between the groups of the patients. However, in "Bricks" the learning was faster in the patients with right hemisphere lesions though there was no difference between the groups in the final performance level.
Conclusions: Discussion: The results suggest that the left hemisphere is mainly involved in shaping of precise trajectory of COP while there is no difference between hemispheres in learning general strategy of voluntary COP control. The study was supported by RFBR 04-04-48989 and 05-04-48610, RFH 06-06-00275 References 1. L.Spinazzola, R.Cubelli, S.Della Sala. Impairments of trunk movements following left or right hemisphere lesions: dissociation between apraxic errors and postural instability. Brain, 2003, 126 (12):2656-66. 2. Perennou D.A, Leblond C., Amblard B, Micallef JP, Rouget E, Pelissier J. The polymodal sensory cortex is crucial for controlling lateral postural stability: evidence from stroke patients. Brain Res Bull. 2000,53(3):359-65. 3. Bobrova E.V. Cortical mechanisms of standing: hemispheric asymmetry (rewiev). J. Higher Nervous Activity (russian), 2007 (in press). 4. Garry M.I., Kamen G., Nordstrom M.A. Hemispheric differences in the relationship between corticomotor excitability changes following a fine-motor task and motor learning. J. Neurophysiol. 2004, 91(4):1570-8

SO-17

Mechanical work in hemiparetic gait

A.C. Christie[1], J.J. Eng[2] and M. Donelan[1]

[1]School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada and [2]School of Rehabilitation Sciences, UBC, Vancouver, BC, Canada

Introduction: Strokes commonly lead to partial paralysis on one side of the body resulting in varying degrees of gait impairment and an increase of up to double the metabolic cost of healthy gait. What explains this elevated metabolic cost? In healthy walking, step-to-step transition work accounts for approx 65% of metabolic energy requirements (Donelan et al., 2002). During the transitions, leading limb negative work is required to redirect the centre of mass from one inverted pendulum-like arc to the next and positive work is required to replace the dissipated energy. Step-to-step transition models predict that the least mechanical work, and thus the least metabolic energy, is required when the trailing leg positive work and leading leg negative work are of equal magnitude and performed simultaneously. This optimal transition hypothesis predicts that the elevated metabolic cost of hemiparetic walking is a result of the paretic leg being unable to perform positive work with the correct magnitude or timing resulting in greater amounts of required work when compared to speed-matched healthy subjects.
Methods: To test this hypothesis, twelve community-dwelling stroke survivor volunteers of minimum six months post-stroke with no significant underlying musculoskeletal issues were recruited. Subjects walked in shoes without orthosis at their fastest comfortable walking speed for five trials. Joint kinematics and individual limb ground reaction forces were collected and inverse dynamics was used to calculate positive work for the paretic and non-paretic limbs from the sum of ankle, knee and hip joint positive work.
Results: The average walking speed was 0.70±0.35m/s. In support of the optimal transition hypothesis, the paretic leg performed only 64% of the work performed by the non-paretic leg (35.9±9.9J and 56.2±12.8J, respectively). The total combined positive work was 92.1±18.7J, a three-fold increase over the work required in speed-matched healthy subjects (30±6J; Donelan et al., 2002).
Conclusions: These preliminary results support the hypothesis that sub-optimal transitions increase the mechanical work required for hemiparetic gait. The observation that the paretic limb performs more work than that required of both limbs in healthy gait suggests that it is the inability to coordinate work rather than limb strength that underlies the increase. Our comparisons between hemiparetic and healthy subjects are limited by the different methods of measuring mechanical work between the two studies and by the fact that it is not possible to tightly control walking speed in hemiparetic subjects. Understanding the mechanical determinants of metabolic cost in hemiparetic gait will facilitate the development of rehabilitation regimens and assistive devices.

SO-18

Inappropriate flexor synergies influence walking mechanics that reduce paretic propulsion in persons with post-stroke hemiparesis

C.L. Peterson[1], R.R. Neptune[1] and S.A. Kautz[2]

[1]Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX, USA and [2]Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA

Introduction: Forward propulsion of the body center of mass (COM) is a central task of walking that depends on the generation of appropriate anterior-posterior ground reaction forces (A/P GRFs). Hemiparetic individuals typically demonstrate asymmetries in A/P GRFs such that the propulsive impulse (i.e., the time integral of the positive A/P GRF) generated by the paretic and non-paretic legs are not equal [1]. During late stance, inadequate paretic leg extension (leg orientation with respect to vertical) and exaggerated flexor muscle activity acting to offload the leg each may contribute to decrease paretic propulsion. The purpose of this study was to gain insight into the underlying causes of the variability in paretic propulsion among hemiparetic individuals. We hypothesized that the paretic propulsive impulse would negatively correlate with paretic hip flexor moment and paretic leg orientation.
Methods: Kinematic data, GRFs and EMG were recorded during walking from 16 persons with post-stroke hemiparesis. Subjects walked at their self-selected speed on a split-belt instrumented treadmill while bilateral EMG was recorded from eight leg muscles including the rectus femoris (RF). Paretic leg stance was divided into four bins: first double support (Bin 1), first (Bin 2) and second (Bin 3) halves of paretic single limb stance, and second double support (Bin 4). Correlation coefficients of paretic hip moment impulse, leg orientation (i.e., angle between foot COM and pelvis COM, positive when the foot is anterior to the pelvis), and EMG activity were calculated with the A/P GRF impulse in each bin for each subject. T-tests of the Fisher transformed coefficients were performed to determine whether they come from a zero mean distribution (i.e., no correlation).

Results: Significant negative correlations were found between the hip flexor moment impulse (p = 0.015, p = .0005) and leg orientation (p = 0.0000, p = 0.0034) with the A/P GRF impulse in Bins 3 and 4. Correlations of paretic muscle activity with the A/P GRF impulse were negative for RF in Bin 4 (p = 0.034).
Conclusions: Strong correlations between leg orientation and A/P GRF impulse suggest that hemiparetic gait kinematics contribute to decreased paretic propulsion. Because extensor muscle force generation accelerates the body when the foot is posterior to the body COM, reduced leg extension likely impairs plantar flexor contributions to propulsion [2]. Furthermore, negative correlations between hip flexor moment and RF activity with the A/P GRF impulse suggest reduced leg extension is likely due to inappropriate flexor synergies in the paretic leg. These results suggest improving hemiparetic walking mechanics by increasing leg extension from mid to late paretic leg stance may provide an effective rehabilitation strategy for increasing paretic propulsion. **Acknowledgements:** Funding was provided by NIH grant R01 HD46820. **References:** [1] Bowden, M.G. et al. (2006). Stroke. 37: 872-6. [2] Neptune, R.R. et al. (2001). J Biomech. 34: 1387-98.

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Aging - Gait control

TO-1

Visually guided step turns: the effect of age on the movement pattern and muscle activation pattern

D. Taylor[1], L. Ngan-Hing[1], N. Shepard[2], A. Ashburn[3], M. Burnett[3] and J. Burgneay[4]

[1]Health and Rehabilitation Research Centre, AUT University, Auckland, New Zealand, [2]Department of Special Education and Communication Disorders, University of Nebraska, Lincoln, NE, USA, [3]The Stroke Association Rehabilitation Research Centre, University of Southampton, Southampton, UK and [4]ISVR, University of Southampton, Southampton, UK

Introduction: Visually guided step turning occurs frequently during daily life yet we have limited knowledge about how turning actions are controlled. Studies of healthy young adults indicated a clear temporal relationship between eye, head, trunk and foot movements during visually guided turning tasks (Hollands et al 2004). We were interested in whether similar relationships occurred in older adults. We were also interested to determine if there was a temporal relationship between lower limb muscle activity and onset of eye or head movement. This study is part of a multi-site initiative to explore the mechanisms underlying instability in older adults and people following stroke. The general hypothesis is that visually guided eye, head and body orientations are a top-down event resulting in stable visual and head orientation prior to full body orientation. Specific hypotheses for this study were; a) the latency to onset of eye movement would increase in older adults; b) a similar temporal order of movement will remain in older adults compared to younger adults; c) preparatory muscle activity would be similar in the turning task as it is during a forward stepping task.
Methods: Ten healthy volunteers between the ages of 20 and 85 years performed visually guided step turns to locations at 30 or 60 degrees of sub-tended arc movement. Electro-oculography was used to measure onset of eye movement, a Qualysis motion analysis system was used to collect 3-D movement data and a Bortec telemetered electromyography system was used to collect muscle activation data from lower limb muscles.
Results: Preliminary data indicates that the latency of onset of eye movement is increased in older adults compared to younger adults ($t = -5.9$; $p<0.001$). The temporal order of eye, head, foot movement also differed in the older adult group in that there was no consistent temporal order of eye and head movement ($W = 0.02$; $p = 0.56$) compared to the younger group ($W = 0.61$; $p <0.001$). The older adults appeared to move their head and eyes at about the same time. Preparatory muscle activity occurred in only 38% of the trials in young adults turning at self-selected speeds, lower than that expected in a gait initiation movement. This low level of preparatory activity may be related to the different postural requirements of gait initiation and step turning in the young adult population. Analysis of the muscle activation data is ongoing.
Conclusions: These findings indicate that the strategy used in visually guided step turning tasks may differ in young and older adults. It was unexpected to find that the older adults tended to move the eyes and head at about the same time as this strategy is unlikely to allow a stable visual platform on which to assist postural control during turning tasks. Further data collection and analysis is required to verify these findings.

TO-2

Evidence for a Link Between Age-Related Visuomotor Decline and Inaccurate Foot Placement During Adaptive Locomotion

G.J. Chapman, W.R. Young and M.A. Hollands

School of Sport and Excercise Sciences, University of Birmingham, Birmingham, UK

Introduction: Previous research has demonstrated that older adults choose to visually fixate stepping targets significantly earlier and for longer than young adults during visually guided walking (Chapman GJ and Hollands MA (2006) Gait & Posture 24(3):288-94, Chapman GJ and Hollands MA (2006) Gait Posture Aug 26; [Epub ahead of print]). We proposed that this altered visual behaviour may represent an adaptive strategy used to compensate for age-related decline in the visuomotor pathways of the central nervous system (CNS). To explore this possibility further we compared the stepping performance of young and older adults under conditions in which we experimentally constrained the duration for which they could look at a target prior to stepping onto it. We predicted that older adults' stepping performance would deteriorate sooner than that of young adults when given progressively less fixation time.
Methods: Eight young participants (23.3±1.3 yrs) and eight older adults (69.2±2.7 yrs) performed 60 trials in which they were required to walk a 10m pathway whilst maintaining gaze on a

cue light placed at eye level at the end of the walkway. Participants were instructed to fixate the cue light until it extinguished, signaling them to redirect their gaze towards a stepping target for their right foot. The cue light extinguished at various points in time prior to the participants' arrival at the target between 0 and 1s). Trials were included in which the cue light did not extinguish during the walk forcing participants to rely on peripheral vision only to complete the task. Foot placement accuracy was assessed using a Vicon Motion Analysis System and gaze behaviour was recorded using the ASL 500 gaze tracker.

Results: Constraining visual behaviour had a powerful effect on the stepping performance of older adults characterised by increased foot placement error and corresponding task failure rate. In contrast, young adults' stepping performance was not significantly affected by our experimental manipulations. Older adults required a foveal image of the target significantly earlier than younger adults (by circa 600ms) in order to achieve comparable stepping performance. Trials in which older adults were not allowed to fixate a stepping target prior to initiating a step, evoked strikingly worse stepping performance than younger adults characterized by significantly greater foot placement error and a task failure rate of over 50% (cf. younger adults < 10%). There were no significant age-related differences in lower peripheral visual field size.

Conclusions: Older adults demonstrate an increased reliance on central vision to perform accurate stepping movements and need this information significantly earlier than younger adults to achieve comparable stepping performance. These findings suggest that age-related changes to the visuomotor system are likely to contribute to falls in older adults and highlight the importance of looking in the right places at the right times during visually guided walking tasks.

TO-3

Aging and the efficiency of steady-state uphill walking

J.D. Ortega[1] and C.T. Farley[2]

[1]*Kinesiology, Humboldt State University, Arcata, CA, USA and* [2]*Integrative Physiology, University of Colorado, Boulder, CO, USA*

Introduction: Introduction: Elderly adults consume more metabolic energy for walking than young adults (5). The efficiency of performing mechanical work is an important determinant of the metabolic cost of walking (3). This study tests the hypothesis that walking is more metabolically expensive for elderly adults because they perform mechanical work less efficiently than young adults.

Methods: Methods: Thirteen young adults (22.3 ± 3.6 years) and twelve elderly adults (74.5 ± 2.9 years; mean ± SD) walked at 1.3 m s-1 on a level treadmill and at five different uphill slopes (1.5, 3.0, 4.5, 6.0 and 7.5% grade). They performed one seven-minute trial per slope. Subjects had no known orthopedic, neurological, or cardiovascular disease and were physically active. Metabolic cost was determined using indirect calorimetry (1) during the last two minutes of each trial. We determined each subject's delta efficiency across the range of slopes from the ratio of the increase in net mechanical power output required to lift the body up the slope and the increase in net metabolic power consumption (2). We assessed the effect of age group on delta efficiency using independent t-tests and assessed the effects of age group and slope on metabolic power using a repeated measures analysis of variance (ANOVA).

Results: Results and Discussion: Elderly adults consumed 12% more metabolic energy during walking than young adults on average over the range of uphill slopes (p = 0.020). In addition, elderly adults performed mechanical work less efficiently (29%, SEM 1) than young adults (33%, SEM 1) across the range of uphill slopes (p = 0.006). Potential reasons why elderly adults perform mechanical work less efficiently than young adults are that they use greater antagonist muscle co-contraction or have a reduction in skeletal muscle efficiency. Co-contraction of antagonists reduces the efficiency of the muscular system because the agonist muscles perform extra positive work and consume extra metabolic energy to overcome the mechanical energy absorption of the antagonists. An alternative mechanism for the lower efficiency of elderly adults might be that there is an uncoupling of phosphorylation and oxidation in skeletal muscle mitochondria (4).

Conclusions: Conclusion: Compared to young adults, elderly adults consume more metabolic energy to travel a meter and perform mechanical work less efficiently during steady-state uphill walking. Although the small reduction in walking efficiency may be a contributing factor, the high metabolic cost of level walking in elderly adults is likely due to other factors, such as greater muscle force generation for supporting body weight. 1. Brockway JM. Hum Nutr Clin Nutr 41: 463-471, 1987. 2. Brooks GA et al. Exercise physiology: human bioenergetics and its applications. Mountain View, CA: Mayfield, 1996. 3. Cavagna GA and Kaneko M. J Physiol (Lond) 268: 647-681, 1977. 4. Marcinek DJ et al. J Physiol 569: 467-473, 2005. 5. Martin PE et al. J Appl Physiol 73: 200-206, 1992.

TO-4

How do shoe features affect dynamic balance and perceived stability during gait?

J. Menant[1], S.D. Perry[2], H.B. Menz[3], B.J. Munro[4], J.R. Steele[4] and S.R. Lord[1]

[1]*Prince of Wales Medical Research Institute, Sydney, NSW, Australia,* [2]*Department of Kinesiology and Physical Education, Wilfrid Laurier University, Waterloo, ON, Canada,* [3]*Musculoskeletal Research Centre, La Trobe University, Bundoora, VIC, Australia and* [4]*Biomechanics Research Laboratory, Wollongong University, Wollongong, NSW, Australia*

Introduction: Although footwear has been linked to falls in older people (1), it remains unclear as to which shoe features facilitate or compromise balance (2). Therefore, this study aimed to investigate the effects of shoe features on dynamic balance and perceived stability during gait in young and older adults, using an approach in which select features of a standard shoe were systematically modified.

Methods: Eleven young adults (mean age: 22.5±2.5 yr) and 15 older adults (mean 73.7±4.2 yr) walked over a level and an uneven surface under 6 randomised shoe conditions (standard, elevated heel, high collar, soft sole, hard sole, and sole with tread). During each trial the ground reaction forces generated during two consecutive steps were captured with 2 force platforms

embedded in the walkway while the three-dimensional kinematic data characterising each subject's gait were collected using two OptoTrak Position Sensors. The relative distance between the total body centre of mass (COM), calculated using a 7-segment model, and the lateral border of the base of support (BOS) during single support phase was calculated and adjusted to step width to represent dynamic balance. A 5-point scale was used to allow the subjects to rate their perception of stability after each shoe condition.
Results: Compared to when wearing the standard shoes, the elevated-heel shoes showed an increase in double support time ($p<0.001$), a reduction in perceived stability rating ($p<0.001$), and, on the uneven surface, greater step width ($p<0.05$). In the high collar and the soft sole shoes both young and older subjects positioned their COM further away from the lateral border of their BOS than in the standard shoes ($p< 0.05$). Only the young subjects perceived the soft sole shoes to be less stable than the standard shoes ($p<0.05$).
Conclusions: Irrespective of a subject's age, shoes with an elevated heel were perceived as a threat to walking stability and led to a more conservative gait pattern, which was accentuated on the uneven surface. In contrast, high collar shoes may have improved dynamic balance control, possibly by providing increased tactile sensory input and mechanical support around the ankle. Soft sole shoes also reduced COM lateral excursion, although more likely in response to mechanical instability of the soles. Despite this finding and contrary to their younger counterparts, the older subjects did not report the soft sole shoes to be unstable, which may be attributed to poorer plantar tactile sensitivity. Soft sole shoes may therefore be detrimental to balance in older people with somatosensory deficits. References 1. Gabell, A., Simons, M.A. & Nayak, U.S. (1985) Ergonomics. 5, 45-48. 2. Menz, H.B. & Lord, S.R. (1999) Journal of the American Podiatric Medical Association. 89,346-57.

TO-5

Dynamic stability of gait in elderly fallers and non-fallers

R. Wright[1], D. Peters[1], P. Robinson[1] and M. Hollands[2]

[1]School of Sport & Exercise Science, University of Worcester, Worcester, UK and [2]School of Sport & Exercise Sciences, University of Birmingham, Birmingham, UK

Introduction: Accidental falls are a leading cause of injury and death in the growing elderly population (Pocinki, 1990). Falls in this population are commonly reported as occurring during walking (Berg et al, 1997). Control of the motion of the centre of mass (COM) and its coordination with the centre of pressure (COP) of the stance foot are important for the maintenance of the whole body's dynamic stability. Differences between young and older adults (Hahn and Chou, 2004) and between older adults with and without balance problems (Chou et al, 2003) have previously been identified in the relative motion of the COM and COP during obstacle walking. The aim of the present study was to determine if there are identifiable differences in the gait kinematics and COM-COP relationships between older adults with and without a history of falling (hereafter called fallers and non-fallers respectively).
Methods: The gait patterns of six elderly non-fallers (mean age 69 ± 5 years) and six elderly fallers (72 ± 5 years) were analysed during level walking at self-selected pace. All participants were community-dwelling, and the faller group had all experienced at least 1 fall in the 12 months prior to testing. A 14-camera Vicon (624) system was used to collect full body kinematic trajectories (60Hz sampling frequency), which were used to calculate COM and temporospatial gait characteristics. Two AMTI force plates were used to measure ground reaction forces used to calculate COP data. Group differences were tested using t-tests. A mixed model ANOVA was used for testing group and left or right side interactions. A significance level of 0.05 was used for all statistical tests.
Results: No significant differences were found between the faller and non-faller groups for any temporospatial gait parameters or for COM-COP separation in the medio-lateral (ML). However, a significant difference was observed between groups in the COM-COP separation in the anterior-posterior (AP) direction at foot strike ($F = 22.61$, $P < 0.01$).
Conclusions: These preliminary results show significantly differences between fallers and non-fallers in the relationship between COM and COP (a measure associated with postural stability) during specific points in time during the gait cycle. These differences cannot be explained by differences in temporospatial aspects of gait (e.g. walking speed, stride lengths etc). The observed differences in the relationship between COM and COP motion could be interpreted as an indicator that older adult fallers have lower dynamic stability in the sagittal plane than non-fallers.

TO-6

Aging affects the steering of locomotion induced by changing optic flows

J.R. Berard[1], J. Fung[1], B.J. McFadyen[2] and A. Lamontagne[1]

[1]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [2]Dept of Rehabilitation, Laval University, Montreal, QC, Canada

Introduction: Perceived self-motion from optic flow is well known to be involved in the control of locomotion [1]. However, there is evidence that aging affects the ability to discriminate directions of 3D optic flow [2]. The purpose of this study is to examine how aging affects the steering of locomotion in response to altered optic flow fields in an immersive virtual environment (VE).
Methods: Five young adults (23±3 years), and eight older adults (66±4 years) participated in the study. Subjects were asked to walk as straight as possible overground while viewing a VE through a head-mounted display unit (Kaiser). The VE viewed by the subjects was a large room displayed as an expanding translational optic flow, with the focus of expansion (FOE) located at neutral, 20° or 40° to the right or left. Kinematic data from the subjects' body movements were collected using a high-speed motion capture system (Vicon). Centre of mass (CoM) position and heading direction in the 3D physical and virtual space were calculated after the subjects walked for approximately 3 meters.
Results: Young subjects were able to make better heading adjustments in the VE as compared to older individuals (Fig. 1A). Young

subjects altered their CoM trajectory so that it was oriented in the direction opposite to the FOE in the physical environment (Fig. 1B) and resulted in small deviation in the VE. The older showed greater variability in their locomotor behaviour, resulting in larger deviation in the VE.
Conclusions: Aging is related to an altered control of steering of locomotion in response to changing directions of optic flow. This may be related to higher discrimination thresholds of optic flow in older adults or altered sensorimotor integration. Funded by Canadian Institutes of Health Research. 1. Warren, WH et al. Nat Neurosci, 2001. 4(2): p. 213-6. 2. Andersen, GJ. and Atchley P. Psychology And Aging, 1995. 10(4): p. 650-658.

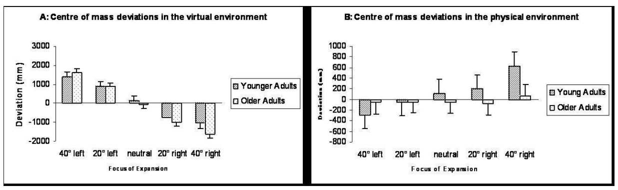

Figure 1. A: CoM deviations in the virtual environment (mean ± 2 standard errors). B: CoM deviations in the physical environment (mean ± 2 standard errors).

Neurophysiology of Sensorimotor Control

TO-7

Multi-segmental control of stance following vestibular and proprioceptive loss

C. Horlings[1], U.M. Küng[1], F. Honegger[1], B.R. Bloem[2], B.G. van Engelen[2] and J.H. Allum[1]

[1]ORL, University Hospital, Basel, Switzerland and [2]Neurology, Radboud University Medical Center, Nijmegen, Netherlands

Introduction: Altered sensory inputs (vestibular, visual or proprioceptive) influence body sway during stance. The question arises whether these cause a change in the amplitude or mode (for example hip or ankle strategy) of sway. We aimed to characterize multi-segmental body motion during quiet stance, and examine the influence of sensory deficits on this motion.
Methods: Six bilateral vestibular loss (VL) patients, 5 bilateral lower leg proprioceptive loss patients (PL) and 20 healthy controls performed five stance tasks for 3 min, or until balance was lost. The tasks were: standing on a firm and foam support, both with eyes open and closed and on a narrow base support with eyes open. We measured pelvis and shoulder angular velocities in pitch and roll planes, as estimates of ankle and hip joint motion, using 2 pairs of body worn gyroscopes. Pelvis to shoulder transfer functions (TF), frequency spectra, and sensory analyses of vestibular, visual, and proprioceptive inputs were calculated.
Results: The form of the spectra was similar across all 3 groups with resonant peaks at ca. 0.4 and 7 Hz indicating a bimodal velocity control for both pitch and roll. VL pelvis and shoulder sway was only marginally greater than controls for all tests, however much greater for standing eyes closed on foam. PL sway was greater than controls for all tests especially for standing eyes closed on a firm surface and eyes open on the narrow base. Sensory analysis using peak to peak amplitudes revealed increased use of visual and proprioceptive inputs in the VL subjects but no changes in the PL subjects. TFs indicated a consistent tendency for shoulder motion to be equal or greater than pelvis motion below 2 Hz and less (more pelvis motion) above 2 Hz. In PL subjects however the TF values below 2 Hz indicated more pelvis than shoulder motion. Results were similar in the roll and pitch planes.
Conclusions: These results indicate that subjects simultaneously use 2 modes to control upright stance relying more on an ankle strategy at low frequencies and an ankle-hip strategy at high frequencies (2 Hz and greater). VL subjects appear to compensate for their loss using other sensory inputs to control stance except when vestibular inputs are required (eyes closed on foam). PL subjects appear not only unable to compensate using other inputs but also need to rely on hip motion to control stance.

TO-8

Muscle activity in the arms and legs of humans is modulated by single low threshold mechanoreceptors in the skin of the foot

L. Bent[1], C. Lowrey[1], K. Thomas[1], J. Fallon[2] and V. Macefield[2]

[1]University of Guelph, Guelph, ON, Canada and [2]Prince of Wales Medical Research Institute, Sydney, NSW, Australia

Introduction: Electrical stimulation of cutaneous nerves in the lower limbs is known to elicit task and phase dependent reflex responses in both the legs (Zehr and Stein 1999) and arms (Haridas et al 2006, Marigold et al. 2003) during locomotion. These reflex responses are suggested to have a role in the maintenance of equilibrium during walking. Use of whole nerve stimulation does not ascertain which of the individual low threshold mechanoreceptors may be involved. Each type of mechanoreceptor relays unique information to the central nervous system and therefore may contribute differently to the maintenance of equilibrium through the generation of appropriate postural strategies. Here, we ask which single cutaneous afferents from the skin on the foot are coupled with motorneurones supplying muscles of the leg and arm.
Methods: Microneurographic recordings from the Tibial (Tib) and Common Peroneal (CP) nerve were collected using tungsten microelectrodes inserted percutaneously into the peripheral nerves. Subjects were positioned either prone; Tib, or sitting; CP. Individual afferents were classified using a conventional identification procedure (Johansson 1978). Each unit was activated for five minutes (through indentation, skin stretch, or stroking) while the subject gently plantarflexed (lower limb) or abducted and extended their arm (upper limb) against the experimenters hand. Surface electromyography (EMG) was sampled from various muscles (gastrocnemius, soleus, tibalis anterior, deltoid, triceps). RMS EMG was spike trigger averaged to the firing of the single cutaneous afferent to investigate modulation of the ongoing muscle activity.
Results: Fifty seven afferents were collected from 20 subjects over 33 recording sessions. Fifty seven percent of the units tested with lower limb muscles showed strong synaptic coupling between single cutaneous afferents and motoneurones supplying muscles about the ankle. Of the four types of afferents in the glabrous skin, the fast adapting type one (FAI) afferents demonstrated the

greatest coupling (81%). For the upper arm, only four cutaneous afferents have been tested (2 FAI, 1SAI, 1hair receptor). Of these four, one FAI located between digit three and four on the foot dorsum modulated the ongoing activity of ipsilateral deltoid.
Conclusions: These results show that there is strong synaptic coupling between single tactile afferents from the foot to motorneurones supplying muscles of both the lower and upper limb. In particular the FAIs appear to have a strong reflex connection to influence motoneurone excitability. These connections highlight an important role for skin in facilitating postural responses to maintain equilibrium, such as stumbling corrective responses and upper limb grasp responses, during standing and walking. References: 1.Haridas, Zehr, Misiaszek, J Neurophys (Epub) 2006. 2. Johansson J Physiol 281: 101-125, 1978. 3. Marigold, Bethune, Patla J Neurophys 89:1727-1737, 2003. 4. Zehr, Stein Progress Neurobiol, Vol 58:185-205, 1999.

TO-9

Ataxia in compressive cervical myelopathy: a role for long-loop responses?

A. Nardone[1], M. Galante[1], M. Godi[1], M. Grasso[1] and M. Schieppati[2]

[1]*Division of Physical Therapy and Rehabilitation, Fondazione Salvatore Maugeri, Veruno (Novara), Italy and* [2]*Department of Experimental Medicine, University of Pavia, Pavia, Italy*

Introduction: Quiet upright stance is maintained through the integration of peripheral afferent input. Vision and proprioception predominate with eyes open (EO) and eyes closed (EC), respectively. Little force is sufficient. Compressive cervical myelopathy (CCM) is a disease that may feature ataxia, particularly with EC. It is not known why ataxia is present only in some patients affected by CCM. Therefore, aim of this study has been to record body sway during quiet stance in a sample of patients affected by CCM of different clinical severity, and to test the hypothesis that ataxia was connected with changes in the somatosensory transmission to the supraspinal centres connected with the cord lesion. To this aim, postural perturbations have been administered in order to evoke early and late EMG responses in leg muscles, the former being transmitted through spinal circuits and the latter through supraspinal pathways.
Methods: We have recruited 16 normal subjects and 14 patients with CCM. Body balance control under quiet stance was studied through a stabilometric platform upon which subjects stood upright with feet spaced 10 cm apart. Sway area (SA) of centre of foot pressure was recorded with EO and EC. Dynamic balance was studied by administering unexpected perturbations consisting of toe-up rotations (3 deg) of the supporting platform at a velocity of 50 deg/s. EMG responses in soleus (Sol) muscle consisted in a short- (SLR) and medium-latency response (MLR). In the tibialis anterior (TA) muscle a long-latency response (LLR) was evoked.
Results: On the average, during quiet stance, SA was much larger in CCM patients than normal subjects, both with EO and EC. During postural perturbations induced by toe-up rotation of the supporting platform, latency of Sol-SLR and MLR to toe-up was similar in both groups (about 45 and 75 ms, respectively). Latency of TA-LLR was about 140 ms in normal subjects but it was further delayed by about 40 ms in CCM patients. A positive relationship was found between SA with EC and latency of TA-LLR in CCM patients.
Conclusions: The increase in body sway in CCM patients is in keeping with the involvement of somatosensory central pathways in CCM, as suggested by the delay of TA-LLR being transmitted through a long-loop pathway possibly damaged by the spinal compression. Conversely, Sol-SLR and MLR are unaffected since these responses are mediated through segmental spinal pathways. These results indicate that somatosensory input to supraspinal centres plays a major role in balance control.

TO-10

Recalibration of locomotor patterns in patients with cerebellar deficits

W. Ilg, R. Roehrig, P. Thier and M.A. Giese

Cognitive Neurology, Hertie Institute for Clinical Brain Science, University Clinic Tuebingen, Tuebingen, Germany

Introduction: While an involvement of the cerebellum in the adaptive control of goal-directed movements is well-established, its role for the adaptation of locomotor patterns is less understood. We investigated the adaptation of locomotor patterns in cerebellar patients (CP) on a treadmill after attaching an additional weight to the right shank.
Methods: We compared 8 CP with degenerative cerebellar disease and 10 healthy controls (HC). Kinematic movement data and the EMG activities of 6 muscles of the right leg were recorded. Subjects executed normal walking (3 trials), walking with an additional weight (3 trials), and again one trial without weight (40-50 step cycles per trial). To reduce the influence of balance deficits subjects held on to the railing of the treadmill during walking.
Results: We found clear correlates of a recalibration of motor patterns, specifically for the velocity of the right hip flexion angle during the swing phase. For HC, hip velocity shows a slight increase in the beginning of adaptation and a strong overshoot after weight removal. For CP hip velocity was decreased in presence of the weight and reached normal levels after weight removal. The analysis of muscle activities reveals different types of adaptive behaviour. For HC, the activity of the Gastronemius med increased for 10 steps at the beginning of the adaptation. After removal of the weight activity was still high in the first step and decreased continuously. CP did not show increased muscle activity in the adaptation phase and did not display comparable after-effects after weight removal. In contrast, other muscles like the adductor longus showed feedback-controlled behaviour, directly reflecting the size of the additional load. Their activity increased immediately after attaching the weight, and decayed instantly after removal. For these muscles activity patterns of CP and HC did not significantly differ. For a more accurate characterization of the adaptation process we learned models that map the EMG patterns (of 6 muscles) onto the trajectory of the knee angle during the swing phase (using Support Vector Regression). Model parameters were estimated from the last adaptation trial (with weight). For HC the prediction error of the trained model decreases significantly over the first 10 steps

of the trial with weight, indicating gradual adaptation of the motor pattern to the weight. Contrasting with this result, CP fail to show such systematic trends of the prediction error.

Conclusions: Our results support an involvement of the cerebellum in the adaptation of locomotor patterns after changes of the limb mechanics. Such recalibration processes seem to affect selectively the activities of specific muscles. CP seem to be impaired with respect to this recalibration process, indicated by decreased adaptation and after-effects. This result supports an influence of the cerebellum in the adaptation of locomotor patterns, potentially by adjusting internal models of limb dynamics.

TO-11

Effects of aging and stroke on sensory recalibration in the control of upright balance

N. Bugnariu[1] and J. Fung[2]

[1]School of Rehabilitation Sciences, University of Ottawa, Ottawa, ON, Canada, [2]School of Physical & Occupational Therapy, McGill University, Montreal, QC, Canada and [3]Jewish Rehabilitation Hospital (CRIR) Research Center, Laval, QC, Canada

Introduction: Loss of upright balance control resulting in falls represents a major health problem for old adults and stroke patients. Postural imbalance may arise not only from motor or sensory impairments but also from the inability to select and reweight pertinent sensory information. We examined the effects of aging and sensory motor deficits following stroke on the capability of the center nervous system (CNS) to resolve sensory conflicts created by virtual reality (VR).

Methods: Stroke patients (52-76 y.o.), age-matched healthy old adults and healthy young (24-35 y.o.) participated in the study. The subjects maintained quiet stance while immersed in a virtual environment (VE) for 1 hour during which a total of 72 visual and/or surface ramp perturbations of 8º (36º/s) were randomly presented. Visual perturbations were induced by sudden pitch or roll plane tilts of the VE viewed through a helmet-mounted display. The kinematic and electromyographic (EMG) responses to pitch or roll plane perturbations were contrasted between subjects across the 4 different conditions of (1) only visual perturbation; (2) only surface perturbation; and combinations of (3) discordant and (4) concordant visual and surface perturbations.

Results: The displacements of the center of pressure (COP) and body's center of mass (COM) increased in the presence of sensory conflicts, significantly more in the stroke patients than older adults. Visual only perturbations produced no muscle activation in young adults, while sporadic muscles activations were present in both old adults and stroke patients. In general, aging disrupted the distal-to-proximal muscle recruitment sequence and the presence of sensory conflicts and stroke exacerbated the inconsistencies. EMG latencies of ankle and hip muscles that were delayed in stroke subjects as compared to healthy older adults during surface perturbations alone, were further prolonged by 40-60 ms in conditions of sensory conflicts. By far the most challenging condition was created by the discordant perturbations with longest onset latencies of neck muscles observed in young adults. This may imply that young adults deal with the mismatch in visual and somatosensory information by either attempting to suppress visual information altogether, or re-weight proprioceptive feedback with increasing reliance. Stroke and healthy age-matched subjects adopted a complete opposite strategy by activating the neck muscles first, demonstrating an excessive reliance on visual inputs or a need to first stabilize their head, a common strategy adopted by people with balance impairments.

Conclusions: Compounding effects of advanced age and neurological injury can skew the sensory recalibration processes required for resolution of sensory conflicts toward an excessive reliance on visual inputs.

TO-12

Cortical activity associated with compensatory balance reactions: Comparison of healthy adults and individuals with neurologic injury

W.E. McIlroy[1], K.M. Sibley[4], J. Camilleri[5], K.F. Zabjek[6] and W.H. Gage[7]

[1]Kinesiology, University of Waterloo, Waterloo, ON, Canada, [2]Toronto Rehabilitation Institute, Toronto, ON, Canada, [3]HSFO Centre for Stroke Recovery, Sunnybrook Research Institute, Toronto, ON, Canada, [4]Institute of Medical Sciences, University of Toronto, Toronto, ON, Canada, [5]Graduate Department of Rehabilitation Sciences, University of Toronto, Toronto, ON, Canada, [6]Physical Therapy, University of Toronto, Toronto, ON, Canada and [7]School of Kinesiology and Health Sciences, York University, Toronto, ON, Canada

Introduction: There is growing understanding of the potential role of the cortex in the control of balance. Recent studies, using electroencephalography (EEG), have revealed cortical activity associated with specific aspects of balance control. Of interest in the present study is the potential role of the cortex in the control of compensatory balance reactions. This study explores the influence of cortical injury on reactions and cortical activity evoked by whole body perturbations. The objective was to determine if differences in compensatory balance reactions measured between paretic and non-paretic upper limbs following stroke were distinguished by differences in evoked cortical responses.

Methods: Selected individuals who had a cortical stroke were tested and compared to healthy adults. A tilting chair paradigm was used to elicit balance reactions. Perturbations varied in amplitude and direction. Unilateral balance recovery responses were tested separately for the left and right upper limbs. Task conditions included both fixed support (hand support prior to perturbation) and change-in-support (required reach-to-grasp) responses. Maximal velocity voluntary limb movements were also performed. Upper limb muscle activity was measured along with limb kinematics and kinetics. Surface EEG was recorded using a 32-channel cap. Galvanic skin responses were recorded from fingers of the non-involved limb.

Results: Perturbation evoked upper limb responses for healthy subjects were characterized by rapid onset latency of EMG responses (110 ms), transient galvanic skin response and an evoked negativity maximal at fronto-central cortical sites (peak amplitude at 150 ms). Initial limb trajectories and grasp aperture changes during change-in-support responses reflected rapid target specific movements. Patient data to date has revealed

slower onset and movement execution for paretic compared to non-paretic limb balance reactions. However, the speed and amplitude of perturbation-evoked reactions, for both paretic and non paretic limbs, exceeded that performed during maximum voluntary reach-to-grasp. Cortical activity evoked in response to perturbation were lower in amplitude when comparing reactions of the paretic versus non-paretic limb.
Conclusions: Results to date highlight the potential role of cortical activity in the control compensatory balance reactions. While previous studies have linked sensory characteristics to the evoked cortical responses the present results highlights the relationship between the cortical activity and characteristics of the evoked response. In addition, the quality and speed of upper limb reach-to-grasp was augmented in response to perturbation (compared with voluntary movements). This, linked with the increased autonomic response, raises the possibility that reach-to-grasp reactions may be uniquely facilitated by whole-body perturbation. This may serve as a possible rehabilitation technique to promote recovery of voluntary control following cortical injury.

Rehabilitation and Training: Parkinson's Disease

TO-13

Contributions of the pre-supplementary motor area, premotor cortex, primary motor cortex, and basal ganglia to anticipatory postural adjustments for step initiation

F. Horak[1], J.V. Jacobs[1], J. Lou[2] and J. Kraakevik[2]

[1]Balance Disorders Lab, Neurological Sciences Institute, Oregon Health & Science University, Beaverton, OR, USA and [2]Dept of Neurology, Oregon Health & Science University, Portland, OR, USA

Introduction: The pre-supplementary motor area (preSMA), dorso-lateral premotor cortex (dPMC), primary motor cortex (M1), and basal ganglia are all thought to contribute to voluntary step initiation, but it is unknown how each of these loci contribute to generating the anticipatory postural adjustment (the APA, a stabilizing weight shift from the swing limb to the stance limb) and foot swing of a voluntary step. In addition, subjects with Parkinson's disease (PD) exhibit impaired APAs, as well as preSMA and basal ganglia dysfunction. We sought to clarify the contributions of the preSMA, dPMC, M1, and basal ganglia to voluntary step initiation, and to determine how dysfunction in the basal ganglia and preSMA contributes to the impaired step initiation of PD subjects.
Methods: Eight PD subjects and 8 healthy subjects performed voluntary steps with their eyes closed, before and after inhibiting the preSMA, dPMC, or M1, in separate sessions, with 1-Hz, sub-threshold repetitive transcranial magnetic stimulation (rTMS). APAs were analyzed from center of pressure displacements recorded from force plates under the subjects' feet, and foot swing was analyzed from the displacements of the subjects' feet, recorded from a motion analysis system.
Results: When compared to the healthy subjects, the PD subjects exhibited increased variability in the duration of their APA, decreased APA amplitudes, and decreased peak foot-swing velocity. PD subjects with the slowest swing velocities exhibited the longest swing durations, and PD subjects with the fastest swing velocities exhibited the shortest swing durations (Pearson $r2 = 0.54$; $P = 0.04$). All significant effects of rTMS lasted for only one trial after stimulation. In both groups, preSMA inhibition decreased APA durations, swing-phase durations, and step lengths. In contrast, dPMC inhibition only shortened swing-phase durations, and M1 inhibition only decreased APA amplitudes. The severity of PD subjects' symptoms correlated with the extent to which preSMA inhibition affected APA durations (Pearson $r2 = 0.70$; $P < 0.01$), and the severity of the PD subjects' symptoms correlated with the extent to which dPMC inhibition affected swing durations (Pearson $r2 = 0.53$; $P < 0.05$). Swing velocity was not affected by rTMS to any site.
Conclusions: The preSMA coordinates the timing of both the postural phase and swing phase of a voluntary step, but then separate neural circuits mediate each step phase, with the dPMC regulating the swing phase and the M1 regulating the APA phase. The basal ganglia regulate swing velocity, independent of the preSMA, dPMC, or M1. In addition, the results suggest that PD subjects exhibit impaired control of APA duration due to a progressive dysfunction of the preSMA, and they utilize the dPMC to lengthen swing duration as compensation for slower swing velocities. This research was supported by grant AG06457 (Horak) and grant F31NS048800 (Jacobs) from the National Institutes of Health.

TO-14

The Effect of Argentine Tango on Functional Mobility in People with Parkinson Disease

M.E. Hackney and G. Earhart

Program in Physical Therapy, Washington University School of Medicine, St. Louis, MO, USA

Introduction: There is emerging evidence that the basal ganglia can be selectively stimulated by rhythmic, metered movement similar to that produced during dancing. Recent work suggests that among the frail elderly, tango dancing may improve functional mobility. The purpose of this study was to determine if individuals with Parkinson Disease (PD) who participated in an Argentine tango dance class would have greater gains in functional mobility than a similar group of subjects with PD who participated in a traditional exercise class.
Methods: Nineteen people with PD were randomly assigned to either a tango dance class or a traditional exercise class. They were evaluated prior to beginning classes with the Berg balance scale, Timed Up & Go test, and they answered a Freezing of Gait questionnaire. Walking and dual task walking velocities were measured with motion analysis. Participants attended one hour classes two times per week for a total of 20 lessons, completed within 13 weeks. They were post-tested with the previous procedures within a week of completing the 20 lessons. Paired t-tests or Wilcoxon Signed Rank tests were used as appropriate to compare pre- to post-test values within the tango and exercise groups.
Results: Greater improvements were noted in the tango group as compared with the exercise group for most measures. Performance on the Berg Balance scale significantly improved for the tango group (pre=46.8, post=50.6, $p=0.003$) but not the exercise group (pre=45.4, post=47.1, $p=0.31$). Performance on the

Timed up & Go test improved for the tango group (pre=10.7 s, post=9.8 s, p=0.11) but not for the exercise group (pre=11.7 s, post=11.8 s, p=0.88). There was a nearly significant improvement in the Freezing of Gait questionnaire for the tango group (p=0.08) but not for the exercise group (p=0.25). There were no significant changes in walking velocity in either group. Dual task walking velocity increased in the tango group (pre=0.53 m/s, post=0.56 m/s) while there was a decrease in the exercise group (pre=0.69 m/s, post=0.63 m/s).
Conclusions: Participants in the tango group improved more than the exercise group on many measures. This suggests that tango may convey benefits above and beyond those experienced through traditional exercise. Future studies with larger samples are needed, as well as studies designed to determine the particular aspects of tango that are most therapeutic for individuals with PD.

TO-15

Parkinson's disease affects whole body pointing movements

M. Tagliabue[1], G. Ferrigno[2] and F. Horak[3]

[1]LNRS, CNRS, Université René Descartes, Paris, France, [2]Biomedical Engineering Dept., Politecnico di Milano, Technical University, Milano, Milano, Italy and [3]Depts of Neurology, Physiology & Pharmacology and Biomedical Engineering, Neurological Sciences Institute, OHSU, Portland, OR, USA

Introduction: Parkinson's disease (PD) motor impairments of bradykinesia, rigidity and poor set switching lead to problems with equilibrium control and an increased risk of falls. Recent studies have suggested that PD patients' motor skill are very dependent upon vision because of their kinesthetic proprioception problems. To determine whether PD subjects' kinesthetic proprioception impairments compromise the coordination between a pointing task and equilibrium maintenance, we compared performances of a whole body pointing task while standing with eyes open and eyes closed. The effect of anti-Parkinson medication on whole body coordination was also investigated.
Methods: Ten subjects with PD (average UPDRS score in off-medication state equal to 38±15) and 10 age-matched control (CTR) subjects were selected. They stood on a force platform and reached with both index fingers to a target located near their forward limits of stability at a distance and height normalized to 50% of their body height. The subjects performed the pointing task with eyes open (EO) and closed (EC). In the EC condition, the location of the target was memorised and it was removed to avoid tactile feedback of target location. PD patients performed the task both ON and OFF medication. Subject's 3D movements were recorded using a motion analysis system with 18 reflective markers. Execution time and pointing error were measured with index finger marker coordinates. Kinematic and morphological data, together with a 15-segment biomechanical model, were used to estimate centre of mass (CM) displacements in the sagittal plane. Movement coordination was evaluated with a principal component analysis on joint angle trajectories.
Results: Without vision, the PD subjects' execution time was slower than CTRs and in the ON medication condition they were even slower. However, in the EO condition, PD and anti-PD medication did not affect execution time. Surprisingly, pointing errors in the EC condition were not affected by PD or by their medication. The final antero-posterior and vertical whole body CM position while pointing were not different between PD and controls in the EO condition. However, in the EC condition, the PD subjects kept their body CM closer to the ankle compared to both the CTRs and to the EO condition. While the CTRs tended to increase their downward CM displacement with pointing in the EC condition, the PD subjects did not. Both the PD and CTR subjects' motor coordination among body segments were very high in both the EO and EC conditions. However, levodopa medication had a negative effect on multisegmental coordination.
Conclusions: Our results show that, although kinesthetic impairments appear to affect PD subjects' whole body pointing strategy, compensatory mechanisms involving slower pointing and a postural strategy ensuring a larger safety margin while pointing allows for pointing precision similar to CTRs. Levodopa medication has a negative effect on postural stability and whole body coordination.

TO-16

The process of integration of visual information during a dynamic equilibrium task in Parkinsonian patients

M. Schieppati[1], A.M. De Nunzio[2] and A. Nardone[2]

[1]Experimental Medicine, Università di Pavia, Pavia, Italy and [2]Centro Studi Attività Motorie, Fondazione Salvatore Maugeri (IRCCS), Pavia, Italy

Introduction: Processing of sensory information, timing operations and set-shifting can be affected in Parkinson's disease (PD). We investigated the capacity and swiftness to pass from a kinaesthetic- to a vision-dependent balancing behaviour.
Methods: 11 on-phase patients and 11 subjects stood on a continuously translating platform (10 cm, 0.2 Hz) and body segment oscillations were identified. EMG was recorded from tibialis anterior and soleus.
Results: Both patients and subjects stabilized head and trunk in space with EO and followed the platform with EC. Constant visual-condition trials were intermingled with trials in which subjects began with EC and opened the eyes in response to an acoustic signal (EC-EO) and vice versa. On shifting visual condition, both patients and normal subjects changed kinematics and EMG patterns into those appropriate for the new condition. However, changes were slower in PD patients than in normal subjects (Fig 1). Further, PD showed a comparatively longer delay in EC-EO than EO-EC shift.
Conclusions: The findings reveal abnormal temporal features of the automatic release of a new postural strategy in response to a shift in the ongoing sensory set in PD, in particular in the change when patients pass from a non-visual to a visual reference. Although static visual feedback is known to reduce patients' reliance on kinaesthetic feedback, shifting to visual reference may not necessarily be supportive in postural tasks that depend on rapid integration of visual input. These results shed light on the temporal features of release of new balancing strategies in response to shifts in sensory set in PD.

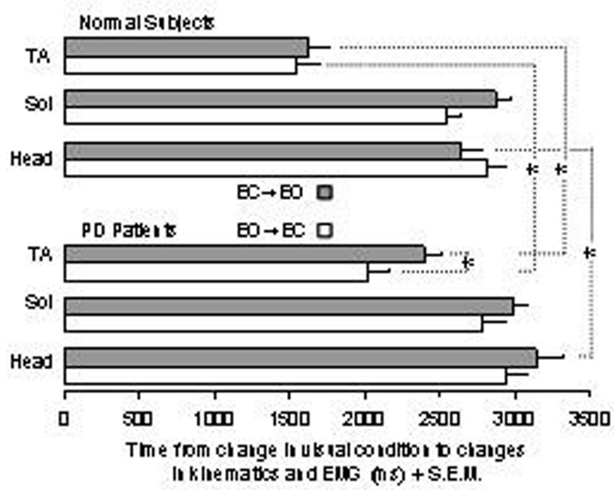

FIG. 1. Time intervals from the changes in visual condition to the changes in balancing behaviour (means from all normal subjects and PD patients). The time interval to change in head oscillation pattern is longer for PD patients than for normal subjects, as is the tibilais time interval, both EO-EC and EC-EO . Moreover, there is a shorter TA time interval in PD subjects for EO-EC compared to EC-EO condition.

TO-17

Postural sway and striatal dopaminergic denervation in Parkinson disease and healthy aging adults

M. Muller[1], G.M. Constantine[2], R.Y. Moore[3] and N.I. Bohnen[1]

[1]*Functional Neuroimaging, Cognitive, and Mobility Laboratory, University of Michigan, Ann Arbor, MI, USA,* [2]*Department of Mathematics, University of Pittsburgh, Pittsburgh, PA, USA and* [3]*Department of Neurology, University of Pittsburgh, Pittsburgh, PA, USA*

Introduction: Nigrostriatal denervation is a key pathobiological abnormality in Parkinson disease (PD), however, to a lesser degree, also occurs in normal aging. PD has been associated with increased postural instability and increased risk of falling. The Unified Parkinson's Disease Rating Scale (UPDRS) is a standard assessment reflecting in part the motor impairments that are associated with PD and perhaps striatal dopaminergic denervation. The objective of this study was to investigate the relationship between measures of postural sway in normal standing, clinical motor measures, and nigrostriatal dopaminergic denervation in PD and normal aging. It was expected that striatal dopaminergic denervation would be associated with decreased postural stability (i.e. increased postural sway) in both healthy aging adults and PD patients. Furthermore, it was expected that the UPDRS motor score would correlate with dopaminergic denervation in PD patients.
Methods: Within group analysis design. Clinically diagnosed PD patients (Hoehn and Yahr stages I-III, N=31, 8 F, 39-79 yrs, 59.5 +/- 10.9 yrs,) and age and sex-matched healthy control subjects underwent C11-β-CFT dopamine transporter (DAT) PET imaging and quiet stance sway assessment. Postural sway was assessed with a posture platform (Type 9286AA, Kistler Instrument Corporation) and characterized by RMS, velocity (V), and the 95% confidence ellipse area (AREA-CE) of the Center of Pressure (COP). PD patients on dopaminergic drugs were tested in the clinically defined 'off' state. PET data were analyzed using volume-of-interest analysis. Striatal DAT binding, UPDRS and sway were statistically correlated (Pearson's r).
Results: Striatal DAT binding was inversely related to age in both patients with PD ($r = -0.428$, $p = 0.016$) and healthy control subjects ($r = -0.537$, $p = 0.008$). RMS and AREA-CE showed significant age-controlled negative correlations with striatal DAT binding (RMS: $r = -0.526$, $p = 0.006$; AREA-CE: $r = -0.491$, $p = 0.011$) in PD patients, but not in healthy control subjects. In PD patients, the UPDRS motor score (Mean = 15.1 +/- 1.5) did not correlate (age-corrected) with striatal denervation and sway measures.
Conclusions: 1) Corrected for age, postural sway in PD patients is a good biomarker for striatal dopaminergic denervation, however not in healthy control subjects. 2) A decrease in striatal DAT binding in PD patients is associated with less stable postural control, i.e. an increase in sway parameters. 3) The absence of a correlation between dopamine denervation and postural sway in healthy adults suggests that postural stability is concomitantly controlled by extrastriatal systems. 4) The UPDRS motor score likely reflects motor impairments that are caused by not only striatal but also extrastriatal degenerations in PD. Supported by NS019608.

TO-18

Axial motor control in Parkinson's disease during upright vertical axis rotation: en bloc and stabilization strategies

D. Solomon[1], E. Grace[2] and K. Robinson[3]

[1]*Neurology, Johns Hopkins University, Baltimore, MD, USA,* [2]*Physical Therapy, University of Pennsylvania, Philadelphia, PA, USA and* [3]*Physical Medicine and Rehabilitation, University of Pennsylvania, Philadelphia, PA, USA*

Introduction: Impaired balance and postural instability are common in PD, especially in the later stages of the disease, resulting in falls and significant disability. Postural control abnormalities typical of other disorders (increased sway, prolonged latency of responses to perturbations) are absent in PD (Horak et al. 1992). Rather, abnormal patterns of muscle activity, sequencing and difficulty adapting to changing support conditions were associated with postural instability in PD. There is an abnormal peak in the power spectrum of spontaneous sway in PD patients between 0.7 to 1.1Hz (Maurer et al. 2003). This is can be modeled by adjusting noise and gain parameters in a sensory feedback model (Maurer et al. 2004). A similar peak was observed during changes in sensory weighting of proprioceptive information in unaffected subjects (Peterka and Loughlin 2004). We utilized a novel paradigm testing the ability to utilize vestibular and proprioceptive information in a dynamic postural control task.
Methods: Subjects stand on a rotating platform with a safety harness in case of a fall. Arms are folded across the chest. Patients perform one of two tasks: during stabilization trials, subjects are instructed to attempt to keep the upper body (head, arms and trunk) stable in space. During en bloc trials, patients attempt to "lock" head, trunk and leg motion to that of the platform. All trials are last for 20 s and are performed with normal illumination. The order of the tasks alternate, with at least 6 trials recorded

in each condition. A sum of sines stimulus containing frequencies between 0.05 and 2.8 Hz is used to control the oscillation of the platform (Keshner and Peterson 1995). The power at all frequencies is roughly equal in the velocity domain. Bode plots (gain and phase as a function of frequency) are constructed to describe the dynamics of the ankle, hip and neck joints. Platform rotation amplitudes are kept within +/- 40°.
Results: Patients were generally well able to change their postural set, switching readily from en bloc to stabilization strategies over consecutive trials. When attempting en bloc rotation, PD patients had an enhanced resonance peak at around 1 Hz. During the stabilization task, PD patients were unable to stabilize the trunk at frequencies below 1.5 Hz.
Conclusions: We have found that during the vertical axis rotation en bloc paradigm, patients with PD show an enhanced peak in the same frequency range as seen during spontaneous sway (PD patients) and in sagittal plane postural control during sensory reweighting (controls). This is consistent with an abnormality in sensorimotor integration. Patients had difficulty stabilizing the trunk in space at lower frequencies. Although patients were able to utilize different axial motor strategies and switch between them, they might have difficulty in sequencing these strategies within a single behavior such as turning.

Wednesday, July 18, 2007

Fear of Falling, Falls and Prevention

WO-1

Evaluation of a perturbation-based balance-training program to train more effective change-in-support reactions in older adults

A. Mansfield[1], A.L. Peters[2], B.A. Liu[3] and B.E. Maki[2]

[1]Institute of Medical Science, University of Toronto, Toronto, ON, Canada, [2]Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada and [3]Department of Medicine, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada

Introduction: Change-in-support (CIS) balance-recovery reactions, which involve very rapid stepping or grasping movements, may play a critical role in preventing falls; hence, a training program that improves ability to execute effective CIS reactions could potentially have a profound effect in reducing falls risk in older adults. This study examines the efficacy of a perturbation-based training program designed to target specific age-related impairments in CIS reactions that have been previously shown to predict increased risk of falling.
Methods: Older adults (64-80 years) with a recent history of falls or instability were randomly assigned to either a 6-week perturbation-based training program (PERT) or a control program (CON) of stretching and flexibility exercises. PERT subjects stood on a moving surface that translated 30cm unpredictably forward, backward, left or right. Stepping and grasping reactions were trained separately; handrails were removed to promote reliance on stepping reactions, and foam blocks were used to prevent stepping during training of grasping reactions. Concurrent cognitive and movement tasks were included to simulate 'real world' balance-loss situations. Perturbation magnitude was progressively increased throughout the program. Compensatory stepping and grasping reactions were evaluated before and after training using both surface-translation and waist-pull perturbations. This allowed for examination of training-specific and generalizable adaptations, respectively. A two-way repeated measures ANOVA with group-by-time interaction was used to assess the effects of training on the reaction features targeted during PERT training: (a) frequency of multiple-step responses, (b) frequency of lateral steps during responses to forward and backward perturbations, (c) frequency of collisions between the swing foot and stance limb when responding to lateral perturbations (while walking in place), and (d) timing of grasping reactions.
Results: Preliminary results (20 subjects) are reported here; data from the complete sample (≈30 subjects) will be presented at the meeting. Although this initial sample has limited statistical power, two of the analyses of responses to surface translations indicated trends in the group-by-time interaction that approached statistical significance (i.e. $p<0.10$). These analyses indicated that PERT training led to a greater decrease in: 1) frequency of multiple-step responses (PERT: 57% decrease, CON: 23% decrease; $p=0.092$), and 2) frequency of foot collisions in response to lateral surface translations (PERT: 74% decrease, CON: 28% decrease; $p=0.068$).
Conclusions: Preliminary results suggest that the perturbation-based training improved some of the targeted features of the CIS reactions. Such results may help to guide the development of more effective falls prevention programs, particularly if generalizable improvements can be demonstrated in the final analysis. Funding: Canadian Institutes of Health Research.

WO-2

Segment contributions to a standing turn in young and old adults under different task constraints

J. Baird and R. VanEmmerik

Kinesiology, University of Massachusetts Amherst, Amherst, MA, USA

Introduction: More than one-third of adults fall each year, with 3-5% of those falls resulting in a fracture. While about 50% of falls occur while walking, about 30% occur while turning. Very little is known about turning movements. A fall while turning is more likely to result in a hip fracture than a fall from a slip or a trip. Hip fractures are more devastating than the wrist fractures that can result from a fall while walking, both in terms of recovery for the individual and in terms of cost for medical care.
Methods: Ten young (25 ± 1.3 years) and 10 older adults (74.8 ± 5.3 years) participated. Subjects stood with one foot on each of two force platforms with feet hip-width apart. Targets (47.5 cm2) were placed at eye level 130° to the right and left from the front of the collection space. A light was placed at eye level two meters from the subject. Prior to each trial, subjects were instructed to turn at a self-selected pace to the right or to the left. When the light was illuminated, they were to begin their turn, acquire the target, and return to face the front of the room. There were two conditions. In condition one (constrained), subjects

were not allowed to move their feet. In condition two (unconstrained), subjects were allowed to move their feet. There were twelve trials in each condition, with direction of turn randomized in advance. A headpiece was fitted with a laser pointer that had to contact the target for the trial to count. Head, trunk, pelvis and foot rotational range of motion were calculated for each trial from retroreflective markers placed on the subject. A one-way ANOVA was performed on the data.

Results: In both conditions, older adults used less head rotation (C1:66° vs 75°, p = 0.0007; C2: 63° vs 72°, p = 0.0006) but greater trunk rotation (C1:18° vs 14°, p = 0.004; C2:17° vs 13°, p = 0.007) than the young adults; there were no differences in pelvis rotation. There were no differences within the groups in the amount of segment rotation used between condition one and condition two. In condition two, the older adults used greater right foot rotation for both left (10° vs 6°, p = 0.0003) and right (14° vs 3°, p = 0.001) turns. There were no differences in left foot rotation for either left or right turns.

Conclusions: When foot placement was constrained, older adults used less head rotation but more trunk rotation than the young adults did. When foot placement was not constrained, the groups used the same relative contribution of the axial segments. The amount of foot rotation used was greater in the older adults for both left and right turns, but only in the use of the right foot. It was expected that the older adults would use greater foot rotation when foot placement was unconstrained, especially in light of using less head rotation. However, there was a great deal of variability in the older adult group. Only about half chose to turn their feet out, and the range of motion varied greatly, from no rotation to 50° of rotation.

WO-3

Obstacle avoidance in people with rheumatoid arthritis

E. Smulders[1], V. Weerdesteyn[2], C. Schreven[1], W. van Lankveld[3] and J. Duysens[2]

[1]Research, Development and Education, Sint Maartenskliniek, Nijmegen, Netherlands, [2]Rehabilitation Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands and [3]Department of Rheumatology, Sint Maartenskliniek, Nijmegen, Netherlands

Introduction: Patients with lower extremity rheumatoid arthritis (RA) may be considered being at increased risk of falling because of impaired mobility, balance and postural stability and diminished strength and proprioception (Sturnieks, 2004; Armstrong, 2005). However, little is known about actual fall incidence and associated risk factors in patients with RA. The few studies on this topic reported that approximately one third of the people with RA experienced at least one fall in the previous year (Armstrong, 2005; Jamison, 2003). This number in the overall population of RA patients equals the proportion of fallers in the elderly (O'loughlin, 1993). In otherwise healthy elderly with a history of falling a reduced ability to avoid obstacles while walking has been shown to relate to increased fall risk (Weerdesteyn, 2006). The aim of this study was to determine whether this potential risk factor for falls would also be present in people with forefoot problems as caused by RA.

Methods: Patients were randomly selected from visitors of our rheumatology clinic. Eleven patients with RA and forefoot problems (8 female, 3 male, mean age 60.3(10.9), range 42-75) were included, as well as 11 healthy age and gender-matched controls. The participants were instructed to avoid obstacles while walking on a treadmill at a fixed velocity of 3 km/hr. The obstacle was always presented to the left foot and was released by a trigger timed by the computer. The obstacle was dropped at 1 of 3 different moments during the step cycle (late stance, early swing and mid swing) to create different levels of difficulty. Late stance obstacle release was the easiest condition, whereas mid swing release represented the most difficult condition. Each condition was repeated 10 times, divided over 2 series of 15 trials. The primary outcome measure was avoidance success rate. Failures were defined as contact of the foot with the obstacle and were noted during the experiment.

Results: Overall, RA patients performed significantly worse at the obstacle avoidance task (Z=–2.423, p= .016). The difference between the groups could be attributed to the mid swing condition. In this condition RA patients were successful in only 62% of trials, whereas controls achieved success rates of 86% (Z=–2.695, p= .006). In the late stance and early swing conditions, both RA patients and controls had nearly optimal performance levels without significant group differences.

Conclusions: Obstacle avoidance in people with RA and fore foot problems is significantly worse than in age and gender matched controls. Because of this they may be at higher risk for falling. However, further understanding of the contribution of this and other risk factors to the relatively high fall rates in people with RA is necessary, in order to be able to design appropriate intervention strategies.

WO-4

Weight loss improves balance control

N. Teasdale[1], O. Hue[1], M. Simoneau[1], A. Tremblay[1], P. Marceau[2], M. Simon[2], B. Simon[2] and B. Félix[1]

[1]Kinesiology, Université Laval, Québec, QC, Canada and [2]General Surgery, Hôpital Laval, Québec, QC, Canada

Introduction: The burden of obesity is widely known for its impact on health from a physiological perspective. For instance, there are associations with diseases such as type 2 diabetes, coronary heart disease, pulmonary dysfunction, musculoskeletal disease, cancer and many others (Bray 2004). The negative outcomes of obesity, however, extend well beyond these aspects. It also modifies body geometry and increases the mass of the different segments (Rodacki et al. 2005). This could have detrimental impact on balance control (Corbeil et al. 2001).

Methods: In a first experiment, we studied the balance control (upright standing posture with and without vision) of 59 male subjects with BMI ranging from 17.4 to 63.8 kg/m^2. A stepwise multiple regression analysis was used to determine the independent effect of body weight, age, body height and foot length on balance stability (that is, mean speed of the center of foot pressure). In a second experiment, we examined if weight loss would improve balance control. Obese men (N=14, mean BMI = 33.0 kg/m^2) were tested before weight loss and at resistance to weight loss (15 to 47 weeks after the first session). Morbid obese men (n= 13, mean BMI = 49.5 kg/m^2) were tested three times: before surgery, after a weight loss of about 20% (12-17 weeks after surgery) and after a weight loss of about 50% (50 to 61 weeks after surgery). For comparison purposes, healthy subjects (N=15, mean BMI = 22.7 kg/m^2) also were tested twice at 6-month interval.

Results: For the first experiment, body weight by itself accounted for 52% of the variance of balance control (speed of the center of foot pressure with vision). Adding age contributed a further 3% to explain balance control. Without vision, body weight accounted for 54% of the variance and adding age and body height contributed a further 8% and 1% to explain the total variance, respectively. The final model explained 63% of the variance noted in the speed of the center of foot pressure. These results show that a decrease in balance control is strongly correlated to an increase in body weight. For the second experiment, obese subjects showed a significant decrease in body weight (on average, 12.3 and 64.8 kg for the obese and morbid obese, respectively) and waist circumference (on average, 12.9 and 49.8 cm, respectively). The weight of control subjects did not vary. With the weight loss, a strong linear relationship was observed between weight loss and improvement in balance control (for example, for CP speed, adjusted $r^2 = 0.65$, $P<0.001$).

Conclusions: Obesity imposes functional limitations pertaining to the biomechanics of activities of daily living (Wearing et al. 2006). Overall, the data provides a compelling case that obesity may predispose the obese to injury by increasing their risk of falling.

Sensory Function in Posture Control

WO-5

Visual field dependence-independence before and after unilateral vestibular loss

L. Borel[1], C. Lopez[1], J. Magnan[2] and M. Lacour[1]

[1]Lab Neurobiologie Intégrative et Adaptative. UMR 6149, Université de Provence/CNRS, Marseille, France and [2]Service d'Oto-rhino-laryngologie et Chirurgie Cervico-faciale, Hôpital Nord, Marseille, France

Introduction: The aim of this study was to analyse visual field dependence-independence changes after unilateral vestibular loss (UVL), to investigate whether subjective visual vertical perception is differently affected in field dependent and field independent patients after UVL, and to examine how subjective visual perception develops in such patients tested longitudinally.

Methods: Experiments were carried out on 31 Menière's patients. All patients underwent unilateral retrosigmoid vestibular neurotomy. They were examined 1 day before surgical treatment and postoperatively throughout the recovery process (1 week, 1 month, and 3 months after surgery). Patients' performances were compared with those of 30 healthy controls. Using the rod and frame test, subjective visual vertical (SVV) perception was tested under four visual contexts: with a frame tilted either clockwise or counterclockwise, with a vertical frame, and without visual reference.

Results: Analysis of SVV perception with a tilted frame clearly identified two distinct subpopulations of field dependent and field independent subjects in Menière's patients and in controls. However, the tilted frame had a larger impact on the SVV in field dependent patients than in field dependent controls. Our data show that UVL did not change the visual field dependence-independence defined preoperatively. Indeed, field dependent patients always had large deviations of the visual vertical towards the frame tilt, whereas field independent patients showed smaller deviations whose direction was independent of the frame tilt. In addition, UVL induced an asymmetry of SVV perception in both subpopulations. Finally, the present study showed that recovery time-course differed according to the frame tilt direction. SVV perception recovered 1 month after UVL for ipsilesional frame tilt, and it remained uncompensated 3 months post-lesion for contralesional frame tilt. Finally, when vertical and horizontal references were provided, SVV was improved in both subpopulations, suggesting that all patients relied on the same allocentric strategy.

Conclusions: The present study indicates that visual field dependence-independence depends on (1) idiosyncratic selection of spatial frames of reference, (2) reliability of vestibular information, and (3) visual context (tilted visual frame, vertical frame, and no visual reference). Unilateral vestibular loss did not change the partition of Menière's patients defined preoperatively but did induce, for all the patients, an asymmetrical visual field dependence with a reduced or abolished contralesional dependence. In addition, our data emphasize the specific status of vertical/horizontal visual references, leading all the patients to refer to a common internal model of references.

WO-6

Directional tuning of neck muscle force produced by linear vestibulocollic reflexes

A. Green[1] and G. Gdowski[2]

[1]Biomedical Engineering, University of Rochester, Rochester, NY, USA and [2]Neurobiology and Anatomy, University of Rochester, Rochester, NY, USA

Introduction: Over 1 million people each year suffer from cervical column distraction injuries related to automobile accidents. These injuries occur due to large movements of the head relative to the trunk during sudden accelerations of the whole body. Despite the high incidence of these injuries the postural reflexes which evolved to stabilize the head on the trunk and protect the neck from cervical column injuries are poorly understood. Recently, Macphereson's group has shown that vestibular evoked limb reflexes activate muscles in a spatially tuned pattern not necessarily related to the pulling direction of the muscle. The fundamental question of this study was: are collic reflexes also spatially tuned?

Methods: We used a three dimensional force transducer attached to the heads of Squirrel monkeys to quantify the forces which act on the animal's head during passive translations of the whole body. In the absence of reflexes the inertia of the head would cause the head to move independently of the body and exert forces on the neck. These passive biomechanics are partially balanced by active reflexive forces produced by the neck musculature which function to control the head and reduce the load on

the cervical column. The forces measured by the force transducer are comprised of both passive biomechanical forces and active reflexive forces generated by the linear vestibulocollic reflex (LVCR). In each experiment, the animal's head was fixed to the force transducer which is in turn fixed with respect to the trunk and the animal's body was translated. The direction of translation with respect to the animal was sequentially altered from side-side translations to fore-aft translations. The stimuli were sinusoids with amplitudes of either 0.25 G or 0.5 G. The frequency of the stimulus was varied across a frequency range of 0.5Hz to 3.36 Hz.
Results: Two important results were observed: 1) vestibular mediated reflexes generate 15-20% more neck musculature force output during translations which are side-side as opposed to fore-aft translations at frequencies greater than 1Hz and 2) at frequencies which are less than 1Hz neck musculature output force during side-side translations increased generating 30% - 60% more force side-side as opposed to fore-aft translations.
Conclusions: These results suggest that the LVCR is most effective at controlling the inertia of the head during low frequency side to side translations. Furthermore, these behavioral observations are consistent with a subpopulation of vestibular only neurons located in the vestibular nuclei that have comparable response properties. Further work will be carried out to determine if this subpopulation of neurons is part of the underlying neural substrate which mediates the LVCR.

WO-7

Non-linear analysis of stabilometric signals can predict Ménière's disease vertigo attacks

P. Gagey[2], O. Sasaki[1], S. Usami[3] and S. Sakura[3]

[1]ENT, aSakura Clinic, Tokyo, Japan, [2]Institut de Posturologie, L'Hay-les-Roses, IdF, France and [3]ENT, Shinshu University, Matsumoto, Japan

Introduction: Vertigo attacks during Ménière's disease are practically impossible to anticipate by currently used techniques. Now, non-linear–analysis algorithms have been developed that can predict critical states, based on an index of the similarity of postural system dynamics between their current state and a reference state, derived from regular stabilometric measurements (Le Van Quyen et al., 1999). Could this similarity index be applied to identify changes of these dynamics before the onset of Ménière's disease vertigo attacks?
Methods: First, random variations of this similarity index were evaluated in a population of normal subjects. Then, 8 patients' measurements were recorded every week for several months and their attacks of vertigo were noted. When the similarity index deviated from its mean value by >4 standard deviations (SD), it was considered to predict a vertigo attack, whether or not it occurred. For comparison, conventional stabilometric parameters were also recorded and, when two of them deviated from their mean values by >2 SD, they were considered to predicted a vertigo attack, whether or not it occurred.
Results: Contingency tables crossing true and false, and positive and negative, predictions showed that the similarity index alone was able to predict vertigo attacks of Ménière's disease ($\chi 2=22.16$; $p<0.001$).
Conclusions: This success of the Le Van Quyen similarity index joins other successful non-linear dynamic analyses of stabilometric signals (Gagey et al., 1998) and merits posturologists' attention.

WO-8

Prosthetic device based on multi-modal feedback improves balance control for the healthy young and elderly

J.H. Allum[1], J.R. Davis[2], M.G. Carpenter[2], S. Meyes[3], R. Tschanz[3], D. Debrunner[3] and J. Burger[3]

[1]University Hospital Basel, Basel, Basel, Switzerland, [2]School of Human Kinetics, University of British Columbia, Vancouver, BC, Canada and [3]Technical University of Applied Sciences, Biel, Bern, Switzerland

Introduction: Biofeedback of body sway is a means of providing alternative sensory inputs to patients with balance impairments to help them avoid a tendency to fall, and thereby improve their quality of life. We investigated whether a combination of bone-conducted auditory, vibro-vestibular, vibro-tactile, as well as visual inputs could improve balance control in the young (20-35 years of age) and the elderly (60-80 years)
Methods: Our approach to improving balance control via artificial sensory biofeedback used a trunk sway measuring device (SwayStar™) strapped to the lower back (close to the COM) to quantify body sway in the roll and pitch directions. The signals from this system were then fed to a microcontroller which then drove various multi-modal transducers mounted on a head band to simultaneously excite auditory, tactile, vestibular and visual sensori- neural systems thus providing several usable balance control signals to the CNS. The thresholds of trunk sway when the feedback first acts, in each sensory mode, was set as an increasing proportion of the population average range of sway for each task without feedback. We requested both groups of subjects to perform a number of stance and gait tasks. Stance tasks included two-legged narrow base stance, eyes closed and open, on a firm and foam support surface, as well as tandem stance eyes open and closed. Gait tasks included tandem gait, simply walking 8 m, and a get-up-and-go-up task. We repeated the tasks a few days later after 20 mins of training with feedback on 4 stance and 3 gait tasks.
Results: Noteworthy 60% reductions in trunk sway angle area, and 40% reductions in trunk sway angle, were recorded in the young and a similar reduction in the elderly. The reductions in trunk sway were clearly present with biofeedback for stance but not for gait tasks. The reductions in sway achieved with stance tasks were positively correlated with the amount of sway without feedback, indicating that in patients with excessive sway with respect to normals, even more significant sway reductions could be achieved.
Conclusions: These results indicate that multi-modal feedback signals applied at the head yielded the most significant reductions in stance body sway recorded to date. Nonetheless, we

need to answer the question whether providing training without feedback or relying on a carry-over effect after training with feedback are equally or less effective methods of reducing body sway.

Biomechanics of Posture Control

WO-9

Shared muscle synergies in the stance leg during stepping and non-stepping postural responses

S.A. Chvatal, G. Torres-Oviedo and L.H. Ting

Department of Biomedical Engineering, Emory University and Georgia Institute of Technology, Atlanta, GA, USA

Introduction: We are interested in neural control of balance during standing and walking. Previous studies suggest the nervous system simplifies muscle coordination in standing postural control by activating muscle synergies rather than individual muscles. In this study, we investigated whether the same muscle synergies used during postural responses where standing balance is maintained without moving the feet are also used during more dynamic postural strategies such as stepping responses, and possibly for postural responses during walking.
Methods: Subjects underwent three sets of support surface translations. In each set, randomized horizontal plane perturbations in 12 directions were presented, and 5 trials were collected for each perturbation direction. During the first set of larger perturbations, subjects were instructed to step with their left leg if a step was necessary. In the second set of smaller perturbations, subjects maintained balance without stepping. In the final set, subjects were perturbed while stepping on the platform during walking. Surface EMG activity was recorded from 16 lower-back and leg muscles on the subject's right side (the stance leg). Four time bins were analyzed to account for temporal variations in muscle activity. Using nonnegative matrix factorization, we extracted muscle synergies from 60% of the non-stepping trials for each subject, and used these to reconstruct the muscle activation patterns from the remaining trials in all conditions (cross validation). We then identified whether additional synergies were necessary to account for muscle activation in the various conditions.
Results: Muscles had different EMG patterns in non-stepping and stepping conditions, both in amplitude and in the perturbation directions evoking muscle activation. In general, muscle synergies from the non-stepping condition were sufficient to reproduce the postural responses in both conditions. In a few subjects, additional task-specific muscle synergies were needed to reproduce the stepping responses, providing greater activation of "ankle" strategy muscles for push-off. On the other hand, muscle synergies important for the "hip" strategy were only used in the non-stepping condition.
Conclusions: Muscle synergies during stance that restore the position of the CoM following a balance perturbation can also be used to displace the CoM during stepping responses. Therefore, the same muscle synergies can be used for increasingly dynamic postural tasks such as postural responses elicited during walking. The use of a generalized set of muscle synergies during different postural strategies and contexts suggests that a common neural mechanism controls balance during static and dynamic balance tasks.

WO-10

The adaptive control of stair descent behavior

L.C. Pelland[1], B. Joss[2], A. Leroux[3], E. Charbonneau[1] and J. Cybulski[1]

[1]*School of Rehabilitation Therapy, Queen's University, Kingston, ON, Canada,* [2]*Human Mobility Research Centre, Kingston, ON, Canada and* [3]*Exercise Science, Concordia University, Montreal, QC, Canada*

Introduction: While some falls on stair descent are associated with one single unpredictable event, most falls result from errors in stepping behavior that arise from the dynamic interaction between control mechanisms and situational and environmental factors. In this study, we use external metronome pacing to 'force' an increase in the speed of stair descent and quantify the concurrent adaptations in the regulation of posture control (indexed by the co-displacement of the body centre of mass, COM, and centre of pressure, COP) and lower limb mechanics in healthy young adults. The effects of central fatigue on adaptive capacity is investigated.
Methods: Participants were twenty healthy young adults (25 to 35 years old). Blocks of five stair descent trials were completed under three external pacing conditions: self-selected (SS) speed and 125% and 175% increase from the SS baseline. Moderate to severe physiological fatigue was induced using the modified Ellestead treadmill protocol. Blocked trials were performed under no-fatigue (NF) state and fatigue (F) state. Ground reaction forces (AMTI; 2000 Hz) and full-body 3-D kinematics (Optotrak 3020, 100 Hz) were recorded; inverse dynamics of lower limb mechanics and time-histories of COM displacement and COP dispersion were computed off-line (Visual 3D). Of interest for COP regulation is the point of inflection in the dispersion profile that identifies the transition from the initial feedforward control to a regulated steady state control of the COP variable. Effects of speed and physiological states were investigated by repeated measures ANOVA.
Results: Behaviorally, the overall paths of the whole body COM were invariant across speed conditions for both NF ($p=0.69$) and F ($p=.96$) states. The underlying regulation of COP and lower limb support were, however, adapted in condition-specific ways. In the NF state, increasing speed of descent produced a linear delay in the point of inflection, indicating that a steady state control of COP is achieved later in the stance phase. This was also associated with a significant increase in lower limb total support moment and joint powers from baseline SS ($p<.05$) that was linear across the two intervals of speed increase (m(ss to 125%)= 12.1 and m(125% to 175%)= 10.6). Fatigue introduced nonlinear relationships between the point of inflection of the COP path and lower limb mechanics, with a non-significant increase in total support moment and power from SS to 125% SS ($p=.17$) along a slope of m= 5.5 followed by a significant step-increase in these variables and slope from 125% SS to 175% SS ($p=.04$; m= 16.6).
Conclusions: The 'forced' speed protocol is an effective method to investigate adaptive processes of posture control during stair descent. Non-linear control of the COP in F state is suggestive of

a reduced window of safe performance and may provide important insight into fall-triggering mechanisms in at-risk populations.

WO-11

Strategies for anticipatory postural adjustments preceding multi-directional pointing in man

J. Leonard, R. Brown and P.J. Stapley

Kinesiology and Physical Education, McGill University, Montreal, QC, Canada

Introduction: Anticipatory postural adjustments (APAs) initiate whole body movements using a feed-forward mode of control. Feedback-based postural responses to unexpected support surface perturbations in multiple directions result in forces that are constrained to a few directions and directionally tuned EMG activity. We investigated if APAs are characterised by a similar force constraint strategy and directional tuning of EMG activity.
Methods: 9 subjects pointed randomly with their preferred (right) arm to 1 of 13 targets placed at 15° intervals at shoulder height and 130% of arm length. EMG from upper and lower limbs was measured bilaterally. APAs were quantified using resultant horizontal forces (FR) and normalized EMG data was plotted as muscle tuning curves in polar coordinates.
Results: Fig 1 shows mean FR vectors for 1 subject during the 50 ms period before movement onset. Forces produced for left side targets showed higher variability and greater magnitude, due to the larger rotational moment required. FR demonstrated 7 main directions of FR, rather than each direction of pointing having a distinct FR. In particular, pointing throughout the mid-range (30-75° and 105-150°) shared a common direction (not significantly different). Leg extensor muscles showed similar inhibition across the 13 directions of pointing, while the flexors had a clear directional tuning.
Conclusions: Forces during the APA period are constrained to a number of directions and muscle activity is directionally tuned during whole body pointing. This strategy may reduce the complexity of the organisation of whole body movements. Most importantly, the results show that force constraint strategies and tuning of EMG activity exists for feedback-based and feed-forward postural adjustments. Funded by CFI, NSERC & FRSQ.

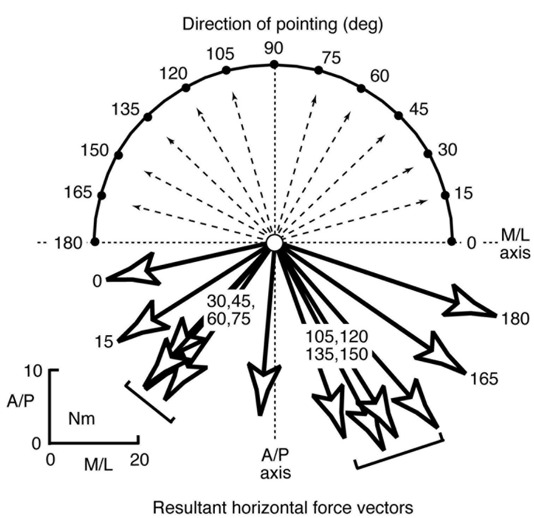

Fig 1

WO-12

The spring-like model for the equilibrium control during human upper trunk bending

A. Alexandrov and A. Frolov

Institute of Higher Nervous Activity and Neurophysiology, Russian Academy of Sciences, Moscow, Russian Federation

Introduction: A large mass of the human upper trunk and a small support limited by the size of the feet, complicate the equilibrium control during the trunk movements. The human body represents a multi-joint chain and due to the dynamic interaction between body links, the relationship between joint torques and joint angles is rather complex. In particular, the direct control of the center of gravity (CG) by the center of pressure (CP) during trunk movement seems doubtful. However, this control is simplified when the movement is described in terms of eigenvectors of the motion equation [1]. In this case, the relationship between CG and CP in the 2-joint (ankle and hip) movement along each eigenvector (eigenmovement) has the same form as for an inverted pendulum. Two eigenmovements exist when a 2-joint model of the human body is considered. By the joint that dominates in each eigenmovement, they can be termed as “Ankle” (A), and “Hip” (H) eigenmovements. It has been shown for bending in the sagittal plane [2] and for quiet vertical stance [3] that, eigenmovements are not only a convenient mathematical abstraction but represent entire motion units under independent control. In the study [3] with the quiet stance, the spring-like model of the equilibrium control based on the eigenmovements was shown to be valid. In the present study, we verify whether during voluntary trunk movements, the similar spring-like model control can explain the observed motor strategy.
Methods: The visco-elastic properties of the body during forward upper trunk bending were calculated by the kinematical responses to the sudden movement perturbations (the sudden platform backward displacements for about 7 cm during 300 ms). The special knee splints were used to block the knees so that the 2-joints (ankle and hip) biomechanical model could be used. Kinematics data were recorded by the retro-reflective markers placed on the body. CP and CG displacements in each of the two eigenmovements were calculated by the inverse dynamics solution. The visco-elastic parameters were calculated using the regression analysis of the relationship between CP and CG in each eigenmovement.
Results: The relationships between CP and CG displacements in A- and H-eigenmovements fit well with a spring-like model with changeable equilibrium state. The stiffness and viscosity are proper to stabilize the movement.
Conclusions: Motor control during forward upper trunk bending could be based on the independent spring-like control of eigenmovements.

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Sunday, July 15, 2007

Aging 1

SP-1

Intense Tai Chi Training and its Effects on Gait in Older, Transitionally Frail Adults

D.E. Waddell[1], C.J. Hass[2], R.J. Gregor[3] and S.L. Wolf[4]

[1]*Department of Exercise Science, University of Mississippi, University, MS, USA,* [2]*Department of Applied Physiology and Kinesiology, University of Florida, Gainesville, FL, USA,* [3]*School of Applied Physiology, Georgia Institute of Technology, Atlanta, GA, USA and* [4]*Department of Rehabilitation Medicine, Emory University, Atlanta, GA, USA*

Introduction: Tai Chi (TC) may be beneficial in remedying locomotor deficits in transitionally frail (TF) elderly (Speechley and Tinetti, 1991). TF elderly are a clinically different subset of the elderly population with Kressig (2004) reporting that their temporal and spatial gait features differ substantially from published reports on more robust older adults. As a growing percentage of our population approaches frailty, it is important to better understand interventions that might ease the transition from robust health to frailty. TC training has been shown to improve anticipatory postural adjustments during gait initiation in TF adults (Hass, 2005) and to reduce the number of falls in TF elderly (Wolf et al., 2003). The purpose of this study was to evaluate the effectiveness of Tai Chi in improving gait in TF adults.
Methods: Six TC forms that exemplify slow, rhythmic movements that emphasize trunk rotation, weight shifting, and coordination were taught to study participants. The TC intervention met 2x/week for 48 weeks. Kinematic gait evaluation was conducted at 60Hz using a six camera 3D Optical Capture system (Vicon Peak, Englewood, CO). Six walking trials were performed at a self-selected pace. Our primary hypothesis was that differences would be observed in the dependent variables pre/post one year of Tai Chi intervention. The dependent variables for relative phase angles were min/max values at designated %'s of the gait cycle. Relative phase angles (RPA) provide a measure of intersegmental coordination and system variability. RPA measures have been used in dynamic system theory (DST) to quantify neuromuscular changes in various populations (Thelan and Ulrich 1991; Clark and Phillips, 1993). Three repeated measure multivariate analysis of variances (MANOVA) were used to test differences across subjects. Paired-T tests were performed for follow-up testing when appropriate. A Paired-T test was also used to assess Mean Absolute Relative Phase (MARP) variability
Results: The max point at toe-off on the Knee-Ankle RPA curve was significantly reduced post intervention ($p < .012$). The MARP variability was significantly reduced at the knee-ankle (pre = 12.17°, post = 9.6°, $p<0.000$) and the hip-knee (pre = 5.9°, post = 4.7°, $p<0.000$). These findings suggest that TC positively altered intersegmental coordination. Improved intersegmental coordination may explain why TC leads to a reduction in falls.
Conclusions: When looking at changes in DST variables as a measure of improved coordination, it appears that 48 weeks of Tai Chi training is effective in improving gait in elderly transitioning to frailty.

SP-2

Effects of Aging on Static, Dynamic and Reactive Balance Abilities

T. Kinugasa and T. Urushibata

Institute of Health and Sport Sciences, University of Tsukuba, Tsukuba, Ibaraki, Japan

Introduction: To assess balance abilities of the elderly and to understand in which circumstances falls are likely, many tests or measures have been developed, notably body sway and standing on one foot (SOF) tests to assess static balance ability, timed up and go (TUG), functional reach (FR) and walking speed tests to assess dynamic balance ability, and the EQUITEST® (Neurocom International) using a moving platform and moving visual surround to test reactive balance ability. However, there are few reports comparing static, dynamic and reactive balance abilities of young adults with those of older adults. Therefore, we examined how these three balance abilities changed with aging .
Methods: Thirty young women (mean age=24.3 yrs), and thirty old women (mean age=68.1 yrs) were recruited. All subjects performed body sway with eyes open and closed, SOF, TUG, FR, normal and maximal speed walking tests, and the EQUITEST®. The EQUITEST® consisted of six sensory organization tests without useful visual or support surface information and created sensory conflict situations, and also included a motor control test to assess the ability of the automatic motor system to recover quickly from unexpected external disturbances.
Results: A multiple stepwise regression analysis using age as the dependent variable showed the inclusion of body sway with eyes open increased the coefficients of determination by 31% (($P<0.0001$), and 10% ($P<0.01$), 5% ($P<0.05$) and 4% ($P<0.05$) of maximal speed walking, the motor control test of the EQUITEST®, and FR, respectively. Factor analysis yielded three factors accounting for 63.8% of total variance in the young group and four factors for accounting for 64.3% in the old. In the young group, the three factors were the Reactive Balance Factor measured by the motor control test of the EQUITEST®, the Dynamic Balance Factor measured by normal and maximal walking speeds, and the Static Balance Factor measured by body sway with eyes open. In the old group, the four factors were the Static Balance Factor, Dynamic Balance Factor, Reactive Balance Factor and Combined Factor (Dynamic Balance + Reactive Balance), respectively.
Conclusions: Static balance, dynamic balance, and reactive balance abilities were maintained in the elderly. Therefore, these three balance abilities should be included in studies trying to predict incidences of falls.

SP-3

Vibrotactile feedback of medial-lateral trunk tilt or foot pressure reduces risk of falling in healthy older adults

K. Statler[1], D. Wrisley[2], R. Karlsson[3], M. Stephens[2], L. Oddsson[3] and C. Wall[1]

[1]Jenks Vestibular Diagnostic Lab, Massachusetts Eye and Ear Infirmary, Boston, MA, USA, [2]Rehabilitation Science, University at Buffalo, Buffalo, NY, USA and [3]Neuromuscular Research Center, Boston University, Boston, MA, USA

Introduction: Sensory substitution devices can provide body orientation and somatosensory information through vibrotactile feedback. The vibrotactile tilt feedback (VTTF) vest provides magnitude and direction of medial-lateral trunk tilt relative to the vertical via an array of tactile vibrators (tactors) that ring the torso. The vibrotactile pressure feedback (VTPF) sock provides magnitude and the direction of pressure distribution under the feet via an array of tactors that ring the lower leg.
Methods: Nine healthy elderly subjects (5 males and 4 females, age: 75.2±2.2 yrs) were tested with each device in two separate sessions. During the first session the Dynamic Gait Index (DGI) and Function Gait Assessment (FGA) were measured for 6 subjects with and without VTTF. Subjects were characterized as healthy elderly based on the Activities-specific Balance Confidence Scale (ABC, 73.2±8.3), Vestibular Disorders Activities of Daily Living Scale (VDAL, mean 2.11), and Berg Balance Scale (BBS, 52.0±0.6). A baseline DGI and FGA without VTTF was measured for each subject. After 30 minutes VTTF training, a second DGI and FGA were measured for each subject while receiving VTTF about ML body tilt from the device. DGI scores increased by 3.7±1.7 from 17.1±0.4 to 20.8±0.3 and FGA scores increased by 2.5±1.2 from 17.8±0.4 to 20.3±0.3 with VTTF. During the second session one month later the DGI and FGA were measured for the original 6 plus 3 additional subjects with and without VTPF. ABC (74.3±7.19), VADL (mean, 1.92), and BBS (51.2±1.4) scores were measured. A baseline DGI and FGA without VTPF was measured for each subject. After 30 minutes VTPF training a second DGI and FGA were measured for each subject while receiving VTPF about foot pressure from the device. DGI scores increased by 2.2±0.5 from 17.7±0.8 to 20.2±0.9 and FGA scores increased by 3.56±0.6 from 18.6±1.1 to 22.0±1.2 with VTPF. Baseline DGI scores in the 6 returning subjects were higher (+1.49) than at the first test session showing improved balance function after one VTTF session.
Results: DGI and FGA items showing the most improvement differed with VTTF and VTPF. For the vest, DGI item 3 (horizontal head turns), DGI item 6 (obstacles), and FGA item 3 (horizontal head turns) showed the greatest improvement. For the sock, DGI item 4 (vertical head turns), DGI item 5 (turn and stop), FGA item 4 (vertical head turns) and FGA item 8 (eyes closed) showed the greatest improvement. Our subjects had a significant increase in DGI score and the average DGI score crossed the threshold for being at decreased risk for falls (> 20) when using the vest or the sock.
Conclusions: Thus, vibrotactile feedback of ML body tilt and vibrotactile feedback of foot pressure both appear to decrease fall risk in healthy elderly subjects. It remains to be determined whether matching the kind of feedback to the kind of impairment (e.g. VTTF with vestibular deficit) can preferentially decrease fall risk.

SP-4

Effect of Tai Chi Training on Balance Control in Subjects with Visual Impairment

W.W. Tsang[1], A. Fu[1], L. Fung[2] and E.H. Tsai[2]

[1]Department of Rehabilitation Sciences, Hong Kong Polytechnic University, Hong Kong, China and [2]Department of Physical Education, Hong Kong Baptist University, Hong Kong, China

Introduction: Previous studies have shown that balance control is poorer in older adults with visual impairment when compared with age-matched control. Questions arise whether their poorer balance control starts at younger age, and whether it can be improved by Tai Chi training.
Methods: The present investigation consisted of a cross-sectional study comparing balance control between subjects with (n=30, mean age=52.2±6.1y) and without (n=31, 50.9±5.1y) visual impairment, and a single-blind controlled trial to investigate the effect of Tai Chi practice on balance control for subjects with visual impairment. All participants underwent 3 balance tests, namely (1) standing under reduced or conflicting sensory conditions, (2) double-leg stance perturbed by forward or backward platform translation, and (3) single-leg stance. Anteroposterior body sway angles under different somatosensory, visual, and vestibular conditions, and perturbed double-leg stance were measured using computerized dynamic posturography, and the durations of single-leg stance were timed. In the prospective study, 14 subjects with visual impairment voluntarily participated in a Tai Chi intervention program; the other 13 undertook music percussion and served as control. Subjects in the Tai Chi group received training in the Yeung style for 1.5 hours, 2 times per week for 4 months. The music participants attended similar number of sessions.
Results: The subjects with visual impairment swayed more in both fixed and swayed-referenced support surfaces under eye open condition; manifested more anteroposterior body sway angles in perturbed double-leg stance; and maintained less duration during single-leg stance when compared to age, gender, height and weight-matched subjects without visual impairment (all $P<0.05$; Figure 1). After intervention, Tai Chi participants showed less body sway in backward platform perturbation than those in control group ($P=0.009$; Figure 2).
Conclusions: Subjects with visual impairment had poorer balance control when compared with those without visual impairment. Tai Chi practitioners showed improvement in

balance control under platform perturbation. Supported by Faculty Research Grant, Hong Kong Baptist University

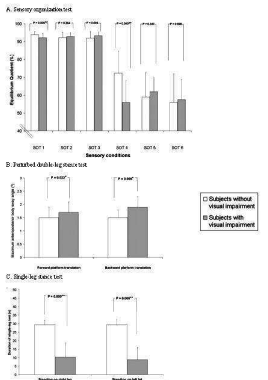


Figure 1. * and ** denote significant difference at P<0.05 and P<0.01, respectively, using univariate tests, after MANOVA showing an overall statistically significant differences at P<0.001 for the 3 balance tests.

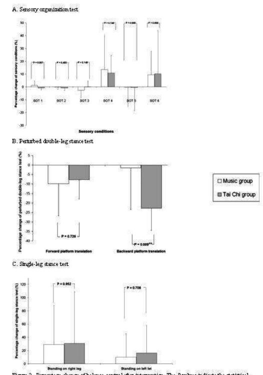


Figure 2. Percentage change of balance control after intervention. The P values indicate the statistical difference using univariate tests, after MANOVA showing an overall statistical difference at P=0.163 for the Sensory organization test, P=0.028 for perturbed double-leg stance test, and P=0.934 for single-leg stance test.

SP-5

Comparison of eye-hand coordination between young and older adults in sitting and standing positions

W.W. Tsang, J.C. Kwok and C.W. Hui-Chan

The Hong Kong Polytechnic University, Hong Kong, China

Introduction: Our daily activities involve eye-hand coordination in standing position. Hence, the ability to maintain a stable upright stance is essential in the initiation and conduction of rapid eye-hand coordination movements. The objective of the present study was to investigate the effects of aging and of posture on rapid index finger pointing.

Methods: This was a cross-sectional study and performed in a university-based rehabilitation center. Participants included young female (n=14; age ± standard deviation [SD], 21.0 ± 1.3 years) and community-dwelling older healthy female subjects (n=14; age ± SD, 69.2 ± 3.8 years). Subjects performed rapid index finger pointing in sitting and in standing to a target (ball) randomly appeared on a visual display unit at three locations, namely "contralateral, center, and ipsilateral" to the center of the screen. Surface electromyography (EMG) electrodes were placed on biceps brachii muscle of the dominant arm to determine the reaction time. The movement time between onset of EMG and touching of screen was recorded. Accuracy was calculated as the absolute error in distance between subjects' touching location and center of ball.

Results: When compared with older healthy adults, young subjects had significantly faster reaction time in finger pointing to the three target locations in standing (overall P = 0.039), but only to the "contralateral" location in sitting (P = 0.006). They showed faster movement time in all target locations in both sitting and standing (P = 0.023 and 0.047, respectively). Young subjects had significantly higher accuracy in standing (P = 0.031) but not in sitting (P = 0.251) than older subjects.

Conclusions: Our findings suggest that the higher demand of postural control in standing probably resulted in the older adults' poorer performance in the overall eye-hand coordination.
Acknowledgement: Area of Strategic Development Grant by The Hong Kong Polytechnic University

SP-6

Differences in demographics, function, strength and sensory function for stable, unsteady and unstable women aged 40 to 80 years

N.L. Low Choy, S.G. Brauer and J. Nitz

Physiotherapy, The University of Queensland, Brisbane, QLD, Australia

Introduction: Strategies that enable early referral for falls education and prevention intervention are required as changes in balance have been detected prior to the 60s. The purpose of this study was to investigate whether women aged 40-80 classified as stable, unsteady or unstable following 10s balance tests were different in measures associated with increased falls risk: demographics, functional ability, strength and sensory system function.

Methods: Measurements were taken of 254 healthy, community ambulant women aged between 40 and 80 years. Demographics (age, height, weight, medication use, co-morbidities, falls history and activity level), clinical functional tests, measures of lower limb strength, vision and somatosensation were measured using previously validated tests. Participants also performed three 10s trials of bilateral stance on foam with eyes closed and unilateral stance eyes open and were categorized as stable (able to complete all trials), unsteady (failed one or two trials) or unstable (failed all trials).

Results: Both balance tasks identified a similar proportion of women who were stable (73% bilateral, 80% unilateral), unsteady (17.5% bilateral, 12% unilateral), and unstable (7.5% bilateral, 8.5% unilateral). For both tasks the unsteady and unstable women were older (2.5% in 40s, 3.9% in 50s, 20% in 60s, and 32.2% in 70s),used more medications, and had more co-morbidities. The unstable category for both tasks were less active and reported more falls. Those who were unstable in the unilateral task were significantly heavier than those categorized as stable and steady. In both tasks, step and the TUG test performances of the unsteady and unstable women were inferior to the stable categories of women. The bilateral stance unstable group was significantly weaker in all lower limb muscles while only hip muscle strength was reduced for those categorized as unstable in unilateral stance. For both tasks the unstable women recorded higher vibration thresholds, greater joint re-positioning error, poorer scores for edge contrast sensitivity and low-contrast visual acuity and showed a trend towards reduced gaze stability. The unsteady women also presented with reduced visual function and vibration sensitivity but reductions in strength were less consistent.

Conclusions: These data provide evidence that women classified as unstable (unable to perform 10s trials of bilateral stance on foam with eyes closed or unilateral stance with eyes opened) also demonstrated a deterioration in multiple factors known to be associated with an increase in falls risk. Further studies are required to determine if these simple quick tests of balance are able to prospectively predict women who may need a more detailed investigation of falls risk factors. The reduction of balance in some women younger than 60 also advocate investigation of optimal screening methods for identification of early deterioration in balance ability and increased risk of falls in some middle-aged women.

SP-7

Effect of aging and physical activity on vertical ground reaction force and time to walk down simulated bus steps with different ground-to-first-step heights

V. Miyasike-da-Silva and L.B. Gobbi

Department of Physical Education, University of São Paulo State, Rio Claro, São Paulo, Brazil

Introduction: Locomotion on stairs is challenging for elderly population mainly in contexts with high step heights, such as a bus. However, physically active persons can perform those tasks efficiently and safely. The purpose of this study is to analyze the effects of physical activity levels on locomotor behavior of persons walking down steps.

Methods: Twenty-nine participants from 23 to 75 years old walked down three steps simulating bus steps. The task was performed under two conditions with varying height between the bottom step and the ground: 28 cm and 43 cm. Ten trials were performed under each condition. Participants were classified in age groups (young adults, middle-aged, older adults, and old-old adults) and according to physical activity level (low, moderate, and high levels), using a questionnaire for daily activities. The peak vertical ground reaction force (vGRF), rate of loading, and total time to perform the task were computed. Each variable was analyzed by a 3-way ANOVA (age x physical activity level x step height) with repeated-measures in the last factor. Significance level set at 0.05.

Results: Older and old-old groups showed a lower vGRF in the high-step condition compared to young and middle-aged groups. The same trend was observed in participants with lower levels of physical activity. A significant interaction between step height and physical levels showed that participants with lower levels of physical activity had lower loading rate values when the step height was higher. The two older groups took longer to perform the task, and it was more pronounced in the 43cm condition. However, independent of age and height of step, participants with higher levels of physical activity showed reduced time to descend the stair. Older participants were more affected by lower levels of physical activity and consequently took longer to climb down the steps.

Conclusions: Results show that aging and low levels of physical activity have the same directional effect on the variables measured in the present study that can reflect on a reduced mobility level. In addition, older individuals are more responsive to increases in environmental demands. However, the maintenance of optimal physical activity levels helps to minimize the reduced physical function caused by the aging process. (Support: Fundunesp, CNPq)

SP-8

Striatal doparminergic denervation and modulation of temporal gait variability in healthy adults

R. Cham[1], S. Perera[2], S.A. Studenski[2] and N.I. Bohnen[3]

[1]*Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA,* [2]*Geriatric Medicine, University of Pittsburgh, Pittsburgh, PA, USA and* [3]*Radiology and Neurology, University of Michigan, Ann Arbor, MI, USA*

Introduction: Dyscontrol of gait rhythmicity reflected by increases in temporal gait variability has been reported in patients with Parkinson's Disease (PD) [1-2]. While this apparent gait impairment has been attributed to basal ganglia dysfunction, it is challenging to disentangle the involvement of striatal dopaminergic pathways due to the complexity of the disease. Although less extensive than in PD, striatal dopamine loss occurs with normal aging. Yet, little is known about the impact of such aging-related striatal dopaminergic denervation (SDD) on the ability to modulate temporal gait variability. The goal of this study is to determine if SDD is implicated in the ability to modulate temporal gait variability in balance-challenging environments, e.g. environments perceived as being slippery.

Methods: Thirty five subjects (17 F, 18 M) between the ages of 41 and 83 years old and with no clinical evidence of defined impairments that affect balance were recruited for participation. [11C]-β-CFT dopamine transporter PET scans were collected to quantify pre-synaptic dopaminergic activity in the dorsal and ventral regions of the striatum. Gait evaluations were conducted to derive a measure of temporal gait variability in two conditions: (1) baseline, i.e. known non-slippery environment, (2) alert, i.e. subjects of the possibility of encountering a slippery floor. Temporal variability of gait was assessed based on the step-to-step fluctuations (RMS) in the duration of the single-support sub-phase of the gait cycle. Within-subject changes in temporal gait variability between Condition 2 and Condition 1 were regressed on age and measures of dopamine both individually and simultaneously to quantify (a) age-related contributions alone, (b) pre-synaptic dopaminergic activity in each striatal site alone, and (c) the simultaneous contribution of age and striatal pre-synaptic dopaminergic activity.

Results: Within-subject change in temporal gait variability between alert and baseline trials was not affected by age. However, decreases in pre-synaptic dopaminergic denervation in the ventral striatum appear to be associated with a limited capability to adjust gait rythmicity when challenged by slippery floor warnings.

Conclusions: The findings of this study suggest striatal dopaminergic mechanisms are involved in the ability to centrally modulate temporal variability of gait in healthy adults. Thus, reduced levels of striatal pre-synaptic dopaminergic activity may partially explain declines in postural control impairments in healthy older adults.——

References [1] Hausdorff JM et al. Experimental Brain Research, 149: 187-94, 2003. [2] Hausdorff JM et al. Movement Disorders, 13: 428-37, 1998. ——Funding support Veterans Administration

SP-9

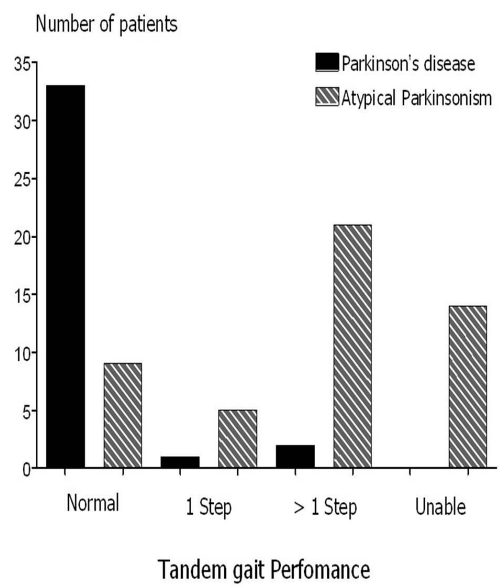
Ten steps to identify atypical parkinsonism

F.W. Abdo[1], G.F. Borm[1], M. Munneke[1], M. Verbeek[2] and B.R. Bloem[1]

[1]*Parkinson Center Nijmegen (ParC),, Radboud University Nijmegen Medical Center, Nijmegen, Netherlands and* [2]*Laboratory of Neurology and Pediatrics, Radboud University Nijmegen Medical Center, Nijmegen, Netherlands*

Introduction: Differentiating Parkinson's disease (PD) from atypical parkinsonism can be challenging, particularly in early stages of the disease. Balance impairment is a frequently encountered problem in patients with Parkinson's disease. A profound balance disorder is an atypical feature, however. Here we analyzed tandem gait performance in parkinsonian patients, to examine its value as an atypical feature.

Methods: We prospectively included 36 patients with PD and 49 with atypical parkinsonism. For the tandem gait test, subjects were instructed to perform ten consecutive tandem steps along a straight line without walking aids and support, with eyes open. Performance was scored as follows: score 0 = no side steps; score 1 = single side step; score 2 = multiple side steps; score 3 = unable to perform more than four consecutive steps in a straight line. Best performance of two trails was scored.
Results: The proportion of subjects with a completely normal tandem gait (score = 0) was significantly lower in the atypical parkinsonism group versus the PD group (table and figure 1). Overall an abnormal tandem gait test differentiated atypical parkinsonism from PD with a sensitivity of 82%, a specificity of 92%. Age-dependent accuracy numbers, using regression analysis, showed that the sensitivity increased with age, while the specificity slightly decreased with age.
Conclusions: These results suggest that tandem gait performance has a good diagnostic ability to differentiate PD from the group of atypical parkinsonian disorders. Tandem gait test is easy to perform, and has a straightforward scoring system. An abnormal tandem gait performance should alert the physician to a possible atypical parkinsonism, as is the case with other so-called "red flags".



SP-10

The influence of speed on walking function after stroke

K. Rudolph[1], D.S. Reisman[1] and C. Wagner[1]

[1]Physical Therapy, University of Delaware, Newark, DE, USA and [2]Program in Biomechanics and Movement Science, University of Delaware, Newark, DE, USA

Introduction: Hemiparesis after stroke leads to slow walking and asymmetry in stride characteristics, joint kinematics and kinetics. Hip motion, and push-off force are vital to normal walking function, and contribute to adequate walking speed in unimpaired individuals, but it is unclear how walking speed influence people with hemiparesis after stroke. Understanding how walking speed changes patterns in people with hemiparesis will likely contribute to more effective treadmill training programs. We present walking patterns in people with hemiparesis after stroke as speed was systematically increased from self-selected free speed to the fastest possible speed. We hypothesized that fast speed walking would lead to improved joint kinematics and improve the symmetry of stride characteristics.
Methods: Kinematics and ground reaction forces were collected with a 3D motion capture system (Motion Analysis Corporation, Santa Rosa, CA) and an instrumented treadmill (Bertec Corporation, Columbus, OH). To date, 4 subjects with hemiparesis walked on the treadmill at their free and fastest possible speed, and 2 speeds in between. Joint angles, trailing limb (TL) position, ground reaction forces and stride characteristics (step length (SL), single limb support (SLS), double support (DS)) were calculated with Visual3D (C-motion, Rockville, MD) and custom designed software (Labview 7.0, National Instruments, Austin, TX). Symmetry of SL, TL position, SLS and DS were evaluated using a ratio of paretic (P): non-paretic (N) variables. Friedman Two Way Analysis of Variance by ranks was used to evaluate differences.
Results: Results can be seen in Table below.
Conclusions: As speed increased, hip flexion during swing and the trailing limb position of both limbs all increased and could have contributed to the longer step lengths on both sides. Pushoff on the hemiparetic limb was also higher at fast speeds but the magnitude of the change was small. The only symmetry measure that improved with speed was SL ratio; no changes were seen in the symmetry of DS or SLS. Faster walking elicited increased step length, joint motions, and ground reaction forces that with training might transfer to over-ground walking which may ultimately improve walking speed in people with hemiparesis and increase their function. Funded by NIH R21 HD047468-01.

	Free	Fast1	Fast2	Fast3
P-SL	0.32 (0.12)*	0.37 (0.12)	0.39 (0.12)	0.43 (0.12)*
N-SL	0.26 (0.10)*	0.31 (0.09)	0.33 (0.10)	0.40 (0.10)*
SL-R	1.25 (0.18)	1.19 (0.21)	1.20 (0.12)	1.08 (0.27)
SLS-R	0.77 (0.28)	0.76 (0.30)	0.71 (0.22)	0.75 (0.21)
DS-R	0.79 (0.33)	0.70 (0.33)	0.80 (0.21)	0.76 (0.16)
TL-R	0.89 (0.45)	0.99 (0.38)	0.97 (0.34)	0.99 (0.32)
PHF	28.2 (2.5)*	30.5 (3.7)	31.0 (3.3)	32.3 (4.2)*
POF	0.022 (0.02)	0.040 (0.040)	0.040 (0.035)	0.050 (0.052)

*$p<0.05$; R=ratio; PHF=peak hip flexion; POF=Pushoff Force

SP-11

Post-stroke gait symmetry: relationship of lower extremity motor impairment, gait velocity and symmetry

K.K. Patterson[1], I. Parafianowicz[2], C.J. Danells[3], V. Closson[3], M.C. Verrier[4], W. Staines[2], S.E. Black[3] and W.E. McIlroy[2]

[1]Graduate Department of Rehabilitation Science, University of Toronto, Toronto, ON, Canada, [2]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada, [3]Heart and Stroke Foundation Centre for Stroke Recovery, Sunnybrook Health Sciences Centre, Toronto, ON, Canada, [4]Department of Physical Therapy, University of Toronto, Toronto, ON, Canada and [5]Toronto Rehabilitation Institute, Toronto, ON, Canada

Introduction: The clinical evaluation of gait is often inadequate and limited to velocity quantitatively despite its importance to the stroke patient and the therapeutic attention it receives. The present study focused on gait symmetry as a potential valuable measure of post-stroke gait. Asymmetry is important due to its potential consequences: challenges to balance control, increased risk of cumulative musculoskeletal injury and gait inefficiencies. The objectives were to (1) determine the prevalence and severity of asymmetry among ambulating stroke survivors, (2) establish the relationship between temporal and spatial indices of symmetry and (3) establish the relationship between symmetry indices, velocity and motor impairment.

Methods: Independently ambulating chronic stroke survivors (n=52) walked across a pressure sensitive mat at preferred and fast speeds. Temporal symmetry (paretic/non-paretic swing-stance ratio) and spatial symmetry (non-paretic/paretic step length) ratios were calculated. Correlations were performed between these ratios, velocity and motor impairment. Normal spatial and temporal symmetry was based on a 95% confidence interval around the mean symmetry ratio for 24 healthy adults (0.9-1.1). Temporal asymmetry was classified as either severe (>1.5) or mild (1.1-1.5).

Results: Thirty (57.7%) participants were temporally asymmetric and 17 (32.7%) were spatially asymmetric (Figure 1, circles). Temporal symmetry is negatively associated with preferred walking velocity ($r=-0.612$, $p<0.01$, df=50) (Figure 1) and motor recovery ($r=-0.742$ $p<0.01$, df=35). These associations appear stronger for individuals with severe asymmetry (triangles) compared to those with mild asymmetry (squares) or normal symmetry (diamonds).

Conclusions: Profound temporal asymmetry was found in many stroke patients classified as "independent" ambulators. Grouping chronic stroke survivors according to temporal symmetry at the preferred speed appears to have some merit in light of the complex relationship of temporal symmetry to motor impairment and velocity. The work highlights the need for a standard assessment of post-stroke gait symmetry.

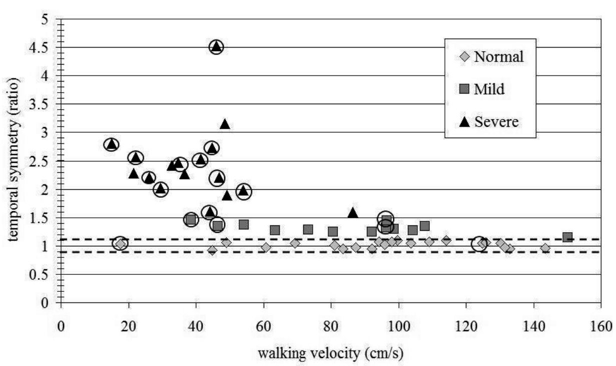


Figure 1. Association between walking velocity and temporal symmetry at preferred speed.

SP-12

Age-related differences in walking stability at different speeds

K.A. Lowry, J. Kerr, N. Lokenvitz and A.L. Smiley-Oyen

Kinesiology, Iowa State University, Ames, IA, USA

Introduction: To better quantify dynamic walking stability, recent studies use trunk acceleration measures to determine harmonic ratios (HRs). This is a measure of smoothness of the walking pattern in which higher ratios indicate a smoother, more stable gait. Previous research with young adults walking from very slow to very fast indicates that harmonic ratios are optimized at one's preferred speed. To date, no study has examined HRs using a range of walking speeds in older adults. The primary purpose of this study was to examine the relationship between harmonic ratios and spatio-temporal gait parameters across a range of speeds using a lifespan approach. We hypothesized that HRs in older adults would be optimized at preferred and disproportionately lower than those in young adults at speed extremes.

Methods: Fourteen young adults (YA, 20-30 yrs. old), 15 healthy older adults (OA, 60-70 yrs. old) and 14 healthy old-old adults (OOA, 80-90 yrs. old) participated in this study. Subjects wore a trunk triaxial accelerometer while walking on paper for 20 meters at 5 self-selected paces ranging from very slow to very fast. Dependent variables included walking speed, stride length and time, cadence, step width and mediolateral (ML), vertical (V), and anterior-posterior (AP) HRs.

Results: There were no group differences in speed in the very slow, slow, and preferred conditions. In fast and very fast, OOA walked more slowly than the other groups. Generally, HRs were lower across groups in the very slow and slow conditions compared to preferred, fast and very fast. At preferred speed, HRs for OOA were lower in both V and AP planes, although there were no group differences in speed, stride length, stride time, step width or cadence. The OOA and YA performed similarly in the slow and very slow conditions while the OA exhibited higher HRs. In contrast, in fast and very fast conditions OOA exhibited lower HRs compared to the YA; the OA HRs were between the two groups. Interestingly, in the ML plane, the YA and OOA groups performed similarly across speeds while the OA group generally exhibited higher HRs. While there were no significant differences in coefficient of variation in spatio-temporal variables, both older groups exhibited a higher coefficent of variation in HR, especially at the faster speeds.

Conclusions: All groups optimized HRs at preferred and fast speeds. However, even at preferred speed, which was similar across groups, the OOA group exhibited lower HRs. Maximal differences between groups were apparent at fast and very fast speeds, with few group differences observed at slower speeds. These results indicate that HRs are more sensitive to group differences than is speed and other spatio-temporal variables. It is concluded that HRs provide unique information regarding global walking stability, and that clinical gait evaluations should include assessment at faster speeds.

SP-13

Comparison of sit-to-stand movement indicators for healthy young and older adults

C.A. Stevermer and J.C. Gillette

Health and Human Performance, Iowa State University, Ames, IA, USA

Introduction: Sit-to-stand (STS) is essential for daily activities and slow performance of STS is associated with fall risk in older adults. To assess STS duration or to compare STS movement patterns, it is necessary to determine points of initiation, seat-off and termination for normalizing movement curves. There is variation among authors regarding STS movement indicators, and

options for kinematic and kinetic measurements of STS performance may be limited by availability of instrumentation in a clinical setting. Our purpose is to determine which variables to use as movement indicators for the analysis of STS and whether these measures are valid in both healthy older and younger adults.
Methods: Nine young adults (33.7 ± 2.6 yrs) and eleven healthy older adults (69.1 ± 5.4 yrs) participated. An eight-camera system tracked reflective markers for 3-D kinematic analysis. Subjects were positioned on a bench-mounted force platform of 48.5 cm height to measure seated reaction forces. With their feet on separate force platforms to record ground reaction forces (GRFs), subjects performed STS with initial foot placements of 90° of knee flexion, 100° of knee flexion, right-staggered and left-staggered. Subjects performed three trials in each condition. Reference values for initiation and seat-off were determined from seated forces, while termination was based on vertical GRF stabilization. Potential movement indicators were compared to reference values for time lead/lag and variability. Indicators included marker positions, marker velocities, joint angles, joint angular velocities, anterior-posterior GRF, and vertical GRF.
Results: Vertical GRF had a time lag from seated GRFs for initiation for both groups (0.48 ± 0.11s for young, 0.55 ± 0.13s for older). Hip angle was also delayed for both groups (0.29 ± 0.15s) for initiation. For seat-off, vertical GRF (0.16 ± 0.04s for young, 0.19 ± 0.06s for older) and hip angle (0.36 ± 0.11s for young, 0.43 ± 0.16s for older) were also differentially delayed between the groups. Anterior-posterior GRF (0.02 ± 0.65s for young, 0.40 ± 0.66s for older) and hip angle (0.10 ± 0.70s for both groups) was delayed in detecting STS termination. Young and older adult results are reported separately when differences are statistically significant ($p<0.01$).
Conclusions: Hip angle appears to be the most consistent kinematic variable for both groups, while vertical GRF is a consistent kinetic variable in detecting initiation and seat-off. Adjusting for bias in these variables may be appropriate for each group, although the clinical relevance needs further evaluation. For termination, hip angle and anterior-posterior GRF are potential indicators with small time shifts and standard deviations. However, STS termination indicators were less consistent between groups and across foot positions, which may indicate an inappropriate reference. Vertical GRF from the lower extremities may not be an appropriate determinant of termination, due to oscillations during stabilization of STS.

SP-14

Do age-related deficits in visual processing predict impaired control of change-in-support balance-recovery reactions?

S.M. McKay, A.L. Peters, C.Y. Scovil, T. Lee and B.E. Maki

Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada

Introduction: Change-in-support (CIS) balance reactions that involve rapid stepping or reach-to-grasp limb movements must be modulated to accommodate environmental constraints, i.e. objects or architectural features that can obstruct stepping or serve as handholds to grasp. The need to monitor the environment suggests a critical role for the processing of visual information, involving various aspects of visual attention, spatial memory and gaze control. Age-related visual-processing deficits are common and have been linked to unsafe driving, limitations in activities of daily living and immobility. The aim of this study is to determine if such deficits predict impaired control of CIS reactions. Based on the results from our ongoing studies, we hypothesize that decline in overt visual attention will be the strongest predictor of motor errors during reach-to-grasp reactions.
Methods: The study involves healthy, ambulatory older adults (age 65-75) who have no neuromusculoskeletal disorders and are free from significant vision deficits. Visual processing and related factors are assessed via tests of covert and overt visual attention, spatial attention, attention switching, vigilance, spatial working memory, executive function, oculomotor control, dynamic visual acuity and depth perception. Potential confounds that could influence CIS reactions are also assessed (e.g. strength, sensory function, balance confidence). Grasping reactions are tested using an extended (2x6m) motion platform configured to simulate an office environment, including a stair, handrail and various visual distracters. The subject is given the task of making a phone call, which requires opening a door and walking to the far end of the platform. The platform is triggered to move suddenly and unexpectedly as the subject approaches the handrail. To prevent adaptation, subjects perform only one trial (their very first exposure to the perturbation and environment). Logistic regression (adjusted for confounding factors) is performed to determine which of the measures related to visual processing predict specific features of the evoked reactions (e.g. errors in grasping the rail, failure to look at the rail).
Results: Pilot testing has been completed and the first two subjects have been tested. One of these subjects overshot the rail during the grasping reaction. Interestingly, this subject failed to look at the rail prior to perturbation onset, suggesting possible impairment of overt visual attention. Results of the logistic regression, based on 32 subjects, will be presented at the meeting.
Conclusions: This study will provide new information about the role that visual processing and related factors play in the control of balance reactions, and how age-related deficits in these areas can impair balance control. The results may ultimately be used to develop new interventions to improve ability to recover balance using CIS reactions. Funding: Canadian Institutes of Health Research

SP-15

Psychomotor desadaptation syndrome and postural control in upright stance

E. Matheron[1], V. Dubost[2], F. Mourey[1] and P. Pfitzenmeyer[1]

[1]*Laboratoire de gérontologie. Equipe INSERM/ERM 207, Dijon, France and* [2]*Groupe Physiologie, Physiopathologie de l'Exercice et du Handicap, Saint-Etienne, France*

Introduction: Increasing age is associated with impairments in postural control. Impaired balance leads to the fall, which is a major problem of public health. The psychomotor desadaptation syndrome (PDS) is a clinical entity observed by Pfitzenmeyer et al. (1999) generally occurring after a fall, involving postural and neurological disorders: muscle tone modification, loss of reactive and protective postural reactions, and psychological features like anxiety and fear of falling. The purpose of this study was to compare postural control in hospitalized older adults with and without PDS.

Methods: Two groups of 10 hospitalized older adults were analyzed: the PDS group (aged 87.3 +/- 4.9 years) with participants having the capacity to maintain upright stance at least 40 seconds and the control group (aged 85.4 +/- 7.9 years). Postural sway (angular velocity and displacement in roll and pitch planes) was recorded for 40 seconds in upright stance using laser gyroscope placed at back lumbar level, under 4 randomized conditions: in natural upright stance, eyes open (EO) and eyes closed (EC), and in standardized position, (EO) and (EC). The comparison was done with ANOVA techniques, the post-hoc by the Scheffé test.

Results: The main result showed a significant alteration of postural control in people with PDS compared with control for EO and EC conditions (respectively $p = 0.026$, $p = 0.028$), but no significant position effect (natural and standardized). For EO conditions, there were interactions (i) between the PDS and body sway plane, in which the displacements were more deteriorated in pitch plane in people with PDS than in control group ($p = 0.004$); (ii) between the PDS, body sway plane and the position, in which the body sway displacements, only in pitch plane, were greater in natural and standardized position in PDS group than in control group (respectively $p = 0.0002$ and $p = 0.015$). There was no significantly angular velocity difference between the 2 groups. For EC conditions, older adults with PDS did not succeed in balance maintenance. When these participants were first kept by a trained evaluator in upright stance EC for 30 seconds, the recordings became possible always with EC, but only done in natural position to account for the already known fatigability of these subjects. These observations could be allotted to their setting in confidence. However, besides the main effect of the syndrome, there was (i) a main effect of the velocity ($p = 0.023$), (ii) an interaction between PDS and body sway plane ($p = 0.02$) which in post-hoc showed recordings that were significantly higher in pitch plane in PDS group than in control group ($p = 0.001$).

Conclusions: Thus, postural control in older adults with PDS was more deteriorated in pitch plane. This postural behaviour seems in agreement with the literature, notably with the backward disequilibrium and the anxious character already described in this syndrome.

SP-16

Visually guided step turns: age effects

N.T. Shepard[1], K. Janky[1], A. Ashburn[2], J. Burgneay[2], D. Taylor[3] and M. Burnett[2]

[1]U of Nebraska, Lincoln, NE, USA, [2]University of Southampton, Southampton, UK and [3]Auckland University of Technology, Auckland, New Zealand

Introduction: In an attempt to better understand the mechanisms underlying the instability and falls risk for post-hemispheric stroke patients a multi-site prospective investigation of visually guided seated and standing turns has been initiated. As an initial step in using a visually stimulated turn seated or standing in post stroke patients more information on normal persons across age is needed. The present project, one of three simultaneous, multi-site coordinated efforts, has the purpose of delineating the onset timing and kinematic relationships for the eye, head and body during visually guided turns as a function of age. Preliminary work of this nature is recently available on young normal subjects suggesting that significant differences occur in the onset timing of eye movement prior to head orientation to a visual target versus eye movements if the task involves whole body visually guided orientation (Holland et al, 2004).The general hypothesis is that visually guided eye, head and body orientations are a top down event securing stable visual and head orientations prior to full body orientation. The specific hypotheses evaluated were: 1. Latency to onset of saccadic eye movements lengthens as the consequences of postural control stability increases, independent of the complexity of the task. (latency will increase going to unsupported sitting and standing but not going from eye only to eye & head to eye, head & body in supported sitting) 2. The relative increase in latency with increasing consequences of postural control stability will be greater in the older adults (> 64 years) than younger adults (< 65 years). 3. The temporal order of movement will remain eye, head, foot independent of age or test condition.

Methods: Normal subject volunteers between the ages of 20-80 years underwent 5 different randomized conditions that ranged from seated to standing and orienting eyes only to eye head and body. Each condition provided for a visual stimulus that starts at primary gaze position disappears and immediately reappears randomly at ±30 or ±60 degrees of sub-tended arc movement. During each of the 5 conditions the outcome parameters were eye velocity (via 2 dimensional video recording at 120 Hz sample rate); angular head velocity in three dimensions; and rate of development of vertical floor reaction force from dual force plates.

Results: Preliminary findings show a lengthening of latency to onset of saccadic eye movement going from the sitting conditions to standing task. Overall the order of segment movements is eye, head then body although individual subject strategy variations were seen. At this printing insufficient numbers had been evaluated to address the age issues.

Conclusions: The findings will be discussed relative to age effects and the concept of a top- down control system that emphasizes stable eye and head positions in the coordination of the whole body orientation to a visual target.

SP-17

Measuring Stride Time Variability: Estimating Test-Retest Reliability and Required Walk Length Using Bootstrapping

S. Perera[1], J.S. Brach[3], J. Talkowski[3], D. Wert[3] and S.A. Studenski[1]

[1]Division of Geriatric Medicine, University of Pittsburgh, Pittsburgh, PA, USA, [2]Department of Biostatistics, University of Pittsburgh, Pittsburgh, PA, USA, [3]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, PA, USA and [4]GRECC, VA Pittsburgh Health System, Pittsburgh, PA, USA

Introduction: Gait variability is associated with falls and walking disability in older adults, and is emerging as an important measure in older adults. Proper estimation of measurement error and immediate test-retest reliability in gait variability requires

walking multiple times, a difficult task for the frail elderly. Keeping walk length to an acceptable minimum will reduce both participant and staff burden, and required physical space. Our objective is to quantify measurement error and immediate test-retest reliability in stride time variability relative to walk length using a statistical bootstrap; and to determine the number of strides needed to achieve a given level of reliability.
Methods: Subjects walked one lap at their usual pace on a 60-meter track while wearing foot sensors (Model TSD111, BIOPAC Systems, Inc., Santa Barbara, CA), recording pressure each 5 milliseconds (ms). The stride times were visually identified from the pressure time series by two raters for each subject. For each subject and each walk length (number of strides) within-subject standard deviation (SD) of stride time SD was estimated using bootstrapping (a relatively new simulation-based approach for estimating the sampling distribution of a complex statistic when the statistic is a summarization of many component data points) with 2000 re-samples per subject per walk length with replacement. For each walk length, between- and within-subject variances and intra-class correlation (ICC) were computed.
Results: Twenty subjects (age 66-86; 8 male; gait speed 0.39-1.56 meters/second) participated. Inter-rater reliability for visual identification of stride times from the foot pressure time series and variability computation was excellent (0.92). For walks with 5, 10, 15, 20 and 25 strides, within-subject SD (measure of measurement error) are 19, 13, 11, 9 and 8 ms, and ICCs are 0.60, 0.77, 0.84, 0.88 and 0.90, respectively.
Conclusions: Measurement error decreases and immediate test-retest reliability increases as the walk length increases. At least 5 strides are needed for fair to good reliability, and approximately 10 for excellent reliability.

SP-18

Outcomes of a gait and balance program in a home care setting

S. Zirges[1], M.L. Walker[2] and B. Van Lunen[1]

[1]*Human Movement Sciences, Old Dominion University, Virginia Beach, VA, USA and* [2]*School of Physical Therapy, Old Dominion University, Norfolk, VA, USA*

Introduction: According to the Centers for Disease Control, falls in persons 65 years and older accounted for over 13,700 deaths and 1.8 million non-fatal injuries requiring emergent treatment. Persons at risk for falling include those with a history of falls and those with health problems that compromise the vestibular, musculoskeletal and/or sensorimotor systems. One hundred two people identified by their primary care provider as being at risk for falls participated in physical therapy home health treatments aimed at fall prevention. Safe Strides is a balance dysfunction program that evaluates the patient with standardized clinical measures to determine the functional needs. The patient's plan of treatment is then developed to target the areas demonstrating deficits utilizing physical therapy interventions and modalities. This is a retrospective study of the outcomes of these patients post-treatment.
Methods: Subjects were community-dwelling adults referred for the Safe Strides fall prevention program. Records were chosen from the subjects treated with the Safe Strides protocol who were also able to complete both an initial and post-treatment Dynamic Gait Index (DGI). The DGI requires that an individual must able to independently ambulate at least 20 feet before administering, and having the ability to follow simple directions. The highest score possible on the DGI is 24. A score lower than 20 has been associated with increased risk of falling. The methods of the study were approved as exempt research by the College IRB. Data extracted from each file included age, sex, number of visits, primary diagnosis, comorbidities, initial score on the DGI and post-treatment score on the DGI. Descriptive and correlative statistics were performed on these data.
Results: One hundred and two subjects (73 females and 29 males)(age=78.46 ±11.306 yrs) with a mean of 12.65 (± 2.864) physical therapy visits made up the study population. The mean DGI score at admission was 10.34 ± 4.36 and the mean DGI discharge score was 17.05 ± 4.769 and the change in the DGI score was 6.73 points ± 3.437. Thirty six of the 100 patients scored below 20 on their initial DGI and 20 or above on their final DGI. Age and number of visits were not significantly correlated with change in DGI score. Subjects with more comorbidities had lower initial scores and less change in score than those who were not as ill.
Conclusions: The Safe Strides program resulted in a mean improvement of 65% on the DGI. More than one-third of participants progressed from an "at risk for falls" score to a "not at risk for falls" score. The results of this study indicate that this physical therapy intervention was effective in a significant number of the study population.

Biomechanics 1

SP-19

Controlling roll and pitch during multi-directional balance perturbations

U.M. Küng[1], C. Horlings[1], F. Honegger[1], J.E. Duysens[2] and J.H. Allum[1]

[1]*ORL, University Hospital, Basel, Switzerland and* [2]*Rehabilitation, Radboud University Medical Centre, Nijmegen, Netherlands*

Introduction: The question arises to what extent roll and pitch movements of the human body during balance corrections are independently controlled [1] or not. Separate control could be absent within muscle synergies due to the orientation of muscle pulling directions. Alternatively, timing requirements of movement strategies, imposed by skeletal geometry may produce separate control in roll and pitch. We employed a new technique involving delaying either the roll or the pitch component of a balance perturbation, in order to determine how roll and pitch commands interact when delivered simultaneously.
Methods: We perturbed the balance of 15 young healthy subjects (23 – 35 years of age) using multi-directional rotations of the support surface. Balance perturbations consisted of combined pitch and roll rotations presented randomly in eight different directions, for which either the roll or the pitch stimulus could be delayed by 150 ms or these could occur simultaneously. Outcome measures were biomechanical responses of the legs,

trunk, arms and head, and surface EMG activity of leg, trunk and upper arm muscles.
Results: Delayed pitch or roll stimuli applied to young normals caused equally delayed shifts (150ms) in peak anterior-posterior (AP) and lateral (LR) center of mass (CoM) velocity without changing the peak amplitude or the total CoM movement at 1 sec. Segment movements followed this pattern with delayed peaks without altered peak amplitudes for the roll and pitch velocities of the pelvis, trunk and head. EMG activity of leg and trunk muscles demonstrated a clear decoupling in balance corrections of roll and pitch. Each muscle showed a roll and a pitch component of varying magnitude, regardless of its axial alignment. M. paraspinalis for example showed an equally large pitch and roll component, with a combined sensitivity pointing back and laterally. Muscles with a large component in one direction still revealed a smaller component in the orthogonal direction for example M. Tibialis anterior in roll and M. Gluteus medius in pitch. When compared to the no delay responses (as the combined response) roll and pitch biomechanical reactions and EMG responses added linearly.
Conclusions: This study shows that roll and pitch components movement strategies and synergies can be programmed by the central nerve system separately to achieve the same end goal. Furthermore this study indicates that components programmed combine linearly to control the roll and pitch movements of the human body. References: 1. Grüneberg C, Duysens J, Honegger F, Allum JHJ. Spatio-Temporal Separation of Roll and Pitch Balance-Correcting commands in Humans. J Neurophysiol 2005; 94:3143-58.

SP-20

Influence of turning on gait initiation parameters

E. Anaka and P. Corbeil

Kinesiology, Laval University, Quebec, QC, Canada

Introduction: The onset of gait initiation, prior to heel off of the swing limb (anticipation phase), is characterised by a backward displacement of the center of pressure (COP) towards the swing limb. This evokes, after a delay due to inertia, a forward displacement of the center of mass (COM) towards the stance limb which leads to the first step (Breniere et al., 1987). Several studies have shown that gait initiation parameters vary according to the starting position [e.g. toe standing (Nolan and Kerrigan, 2003)], or the characteristics of the intended gait such as speed (Breniere et al., 1987) and the anterior-posterior direction (do Nascimento et al., 2005). However, there is still a need to study the effects of turning on gait initiation parameters.
Methods: Healthy young adults initiated gait with their right limb (swing) from a force platform embedded into a 3m walkway. Participants initiated gait facing the walkway (0°) as well as from starting directions of 15, 30 and -15° counter-clockwise. When given an auditory start signal, participants initiated gait in the direction of the walkway and continued for ~2½ walking cycles. Lower limb kinematics and muscle activity along with COP displacements were analysed. Heel and toe contacts of each limb were recorded using switches.
Results: Preliminary analysis revealed that COP displacement at the beginning of the anticipation phase occurred in the same direction as the walkway whether gait was initiated at the 0, 15, 30 or -15° starting directions (Fig. 1). Furthermore, compared to the 0° starting direction the duration of the anticipation phase decreased at the positive starting angles (-3 and -11ms for 15 and 30°, respectively) and increased at the negative starting angle (+8ms for -15°).
Conclusions: Adapted variations of muscular forces produced prior to swing heel off initiate gait in the desired direction. The current findings suggest that the timing and the position of the subsequent steps are also highly dependent on the starting direction.

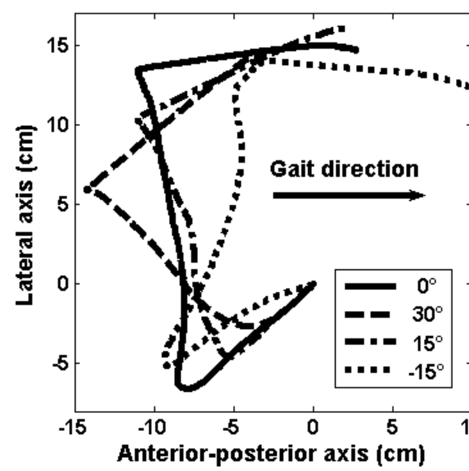


Figure 1 COP displacement during the anticipation phase of gait initiation with regards to starting angle.

SP-21

Comparison of gait performance between Duchenne muscular dystrophy and healthy children with consideration for the effect of gait velocity

N. Gaudreault[1], D. Gravel[2] and S. Nadeau[2]

[1]*Centre for Interdisciplinary Research in Rehabilitation (CRIR), Montreal Rehabilitation Institute, Montreal, QC, Canada and* [2]*School of rehabilitation, University of Montreal, Montreal, QC, Canada*

Introduction: Duchenne muscular dystrophy (DMD) is characterized by progressive muscle weakness, muscle fatigue and the development of joint contractures. These impairments lead to kinematic and kinetic modifications in gait performance. Since DMD children demonstrate a decreased natural gait velocity, one cannot tell if observed differences in gait data profiles of DMD children are due to the disease itself or to the effect of velocity. The present study describes DMD children gait characteristics through 3D biomechanical analysis relative to healthy children with consideration for the effect of gait velocity.
Methods: Eleven children with a confirmed diagnosis of DMD and fourteen healthy subjects matched in age participated in this study. Kinematic gait parameters were measured with an infrared movement analysis system (OPTOTRAK, Northern Digital) using 3D co-ordinates obtained from markers placed on the body segments. Ground reaction forces were recorded using force plates embedded in the floor. The net moments at the hip, knee and ankle joints were calculated using an inversed dynamic

approach. The data profiles of the DMD children at natural gait velocity were compared to those of the healthy children who walked at both natural and low gait velocities. A Student t-test procedure was chosen to examine the significance of the observed differences between the groups for time-distance variables and mean peak values of selected kinematic and kinetic variables at the hip, knee and ankle joints.

Results: At a natural gait velocity, the healthy children walked faster than the DMD children, but the cadence was similar in both groups. However, when the healthy children walked slower, the velocity was not statistically different, but there was a difference in the cadence (78.4 ± 10.1 DMD vs. 100.4 ± 8.4 healthy; p=0.00). There were no differences in the kinematic variables except for a greater hip peak flexion angle during the swing phase observed in the DMD children when the low velocity gait data were compared to that of the healthy children (20.3° ± 10.3 vs. 9.6° ± 9.3; p=0.02). As regards the kinetic variables, the DMD children had lower hip and knee extensor peak internal moments than the healthy children at both velocity comparisons (natural velocity comparison: -0.19 Nm/kg ± 0.10 vs. -0.55 Nm/kg ± 0.17; p=0.00 at the hip and 0.07 Nm/kg ± 0.11 vs. 0.32 Nm/kg ± 0.30; p=0.01 at the knee; low velocity comparison: -0.19 Nm/kg ± 0.10 vs. -0.33 Nm/Kg ± 0.13; p=0.01 at the hip and 0.07 Nm/kg ± 0.11 vs. 0.21 Nm/kg ± 0.15; p=0.02 at the knee).

Conclusions: Whether comparisons were made with similar velocity (low velocity healthy vs. natural velocity DMD) or similar cadence (natural velocity healthy vs. natural velocity DMD), the DMD children showed decreased mean peak extensor moments at the hip and knee joints. Thus, these changes appear to be specific to the disease process because they are not related to either gait velocity or cadence.

SP-22

Biomechanical energy harvesting: device performance and physiological effects

V. Naing[1], Q. Li[1], J.A. Hoffer[1], A.D. Kuo[2], D. Weber[3] and M. Donelan[1]

[1]School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada, [2]Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI, USA and [3]Department of Physical Medicine & Rehabilitation, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: Human power is an attractive energy source because of the high energy/mass ratio of food, the efficiency at which humans convert food into mechanical power and the high mechanical power outputs attainable by humans. During walking, the muscles perform positive and negative work on the body that cancels mechanically but adds metabolically. Consequently, we hypothesized that an appropriately placed and designed generator can perform a component of the required body negative work producing substantial electrical power without altering gait mechanics and without increasing the metabolic cost of the user.

Methods: To test this hypothesis, our research team has developed the wearable biomechanical energy harvester (WBEH) which selectively harvests energy during certain periods of the gait cycle (see Li et al. abstract). It acts about the knee joint because the knee mainly performs negative work during walking. When the device is operating in its mutualistic mode, it selectively engages power generation during the late swing phase when knee flexor muscles appear to be performing negative work. This selective engagement is achieved using a roller clutch to engage power generation only during knee extension; the mechanical resistance to knee flexion is very small. It also requires a control system that processes sensed knee kinematics and engages power generation at the end of swing using an electrical switch. When generation is disengaged in early stance, inertial and frictional resistance to knee motion is relatively small. We tested our hypothesis on 3 male subjects wearing WBEH bilaterally and treadmill walking at 1.5m/s. Subjects walked for 20 min under three conditions: 1) mutualistic mode. 2) switch-engaged mode: with the switch is closed, the device harvests whenever the knee is extending including periods when muscles may be performing positive work. 3) gear-disengaged mode: the user walks with the device weight but without device motion.

Results: The mean electrical power harvested from both legs in mutualistic mode was 4.4±0.7W. The body's maximum efficiency of converting chemical to mechanical energy is approx. 25%, and the WBEH converts mechanical to electrical energy at a measured 50% efficiency. Accounting for these efficiencies, the minimum increase in metabolic cost of generating electrical power with positive muscle work is, on average, 34W. However, we found no significant increase in mutualistic mode metabolic cost over the gear-disengaged condition (1±6W, p = 0.43). On average, 6.3±0.4W electrical was harvested in the switch-engaged mode. The additional 1.9W electrical exacted a 14±12W increase in metabolic cost equating to a 29% chemical to mechanical efficiency as predicted from performing additional positive muscle mechanical work.

Conclusions: During mutualistic energy harvesting, step frequency and knee kinematics are quite similar to the gear-disengaged mode; energy can be harvested without substantially altering gait mechanics or increasing metabolic cost.

SP-23

Isolating step-to-step transitions using sagittal plane rocking

C.H. Soo and M. Donelan

School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada

Introduction: During walking's step-to-step transitions, the leading leg does negative mechanical work to redirect the centre of mass from the inverted pendulum arc of the trailing leg to that of the leading leg. Positive work must be performed to replace the dissipated energy and this is accomplished in healthy walking by pushing-off with the trailing leg. The total amount of work increases strongly with step length and appears to exact a proportional metabolic cost accounting for approx. 65% of the total. This is a limited precision estimate as it is difficult to isolate transitions from other major contributors to metabolic cost, such as leg swing. A possible solution is to isolate walking's transitions by rocking backwards and forwards thereby eliminating leg swing. To be a valid surrogate, we hypothesized that rocking must exhibit the following characteristics of walking's step-to-step transitions: a) the leading leg does negative work and the trailing leg does

positive work during transitions, b) mechanical power increases with increasing step length and c) increases in mechanical power exact a proportional increase in metabolic power.
Methods: 10 subjects rocked in the sagittal plane at 5 step lengths (40-80% of leg length). A metronome enforced their rocking frequency to the preferred frequency measured during the 60% condition. Each trial was 6 min in duration. We collected ground reaction forces using force plates, joint kinematics using a motion capture system and O2 consumption and CO2 production using a metabolic cart. We estimated metabolic power from the steady state O2 and CO2 values. The average leg mechanical powers were determined using the individual limbs method (Donelan et al., 2002). We tested whether mechanical and metabolic power increases with length using one-way repeated measures ANOVA. We tested for a relationship between metabolic cost and mechanical work using linear regression.
Results: As in walking, the leading leg performed negative work during the transition and the trailing leg performed positive work. This pattern held irrespective of rocking direction. The total mechanical power increased by 65% between the shortest and longest lengths (from 0.16±0.05 W/kg to 0.26±0.04 W/kg; $p = 6.3e-5$). Similarly, metabolic power increased by 106% (from 1.3±0.5 W/kg to 2.6±0.8 W/kg; $p = 1.7e-9$). The slope of the best-fit linear regression line between metabolic and mechanical power, a measure of muscle efficiency, was 0.07±0.03 (r^2=0.96).
Conclusions: With one caveat, our results support the use of sagittal plane rocking as a paradigm for studying step-to-step transitions in isolation of other contributors to walking's metabolic cost. Muscle efficiency, the divergent characteristic, is lower than that expected from previous walking experiments (Donelan et al., 2002). Our current analysis seeks to understand this difference and our future experiments will embrace the simplicity of the rocking paradigm to study the determinants of the metabolic cost of pathological gait.

SP-24

Effect of foot position on the centre of pressure profile during sit-to-stand task in healthy controls and patients with hemiparesis

C. Duclos[1], S. Nadeau[1], D. Gravel[1] and J. Lecours[1]

[1]Centre for Interdisciplinary Research in Rehabilitation, Montreal Rehabilitation Institute, Montreal, QC, Canada and [2]Ecole de readaptation, Université de Montréal, Montreal, QC, Canada

Introduction: The transfer from sitting to standing is highly demanding on dynamic stability since it requires the upper-body segment to move forwards and upwards quite quickly. Previous studies have shown the influence of foot position on weight-bearing asymmetry but none has reported its effect on the asymmetry of the centre of pressure (CP) relative to the base of support during the whole task. This would provide data about dynamic stability requirements during the task.
Methods: Seventeen subjects (mean age: 51.7±12.3 yrs) with chronic hemiparesis due to stroke and 14 controls (56.2±11.3 yrs) were asked to stand up from a chair at their natural speed from an instrumented chair adjusted to the individual's knee height. The chair seat was equipped with force platforms measuring the forces under each thigh. Forces under each foot were measured by two force plates embedded in the floor. An Optotrak system recorded the 3D kinematics. Two foot position conditions were assessed: spontaneous and asymmetric, with the affected (stroke patients) or dominant (healthy subjects) foot placed behind. To quantify the asymmetry, the lateral deviations of the CP from the midline of the base of support were calculated at each 10% of the task with positive values indicating deviations towards the affected or dominant side. Statistical analyses (3-way ANOVA, and t-tests) were used to assess the effects of foot position, and subjects' groups on the CP asymmetry at various percentages of the task.
Results: In the spontaneous foot condition, the stroke patients were significantly more asymmetrical than the controls, with their CP deviating laterally towards the non-paretic side (max. values: -34.5±34.6cm vs. -3.5±8.4cm; $p<0.05$) when standing up. This was observed in the middle of the task, from 10% before seat-off to 30% after. With their paretic foot placed behind the non-paretic foot, the patients' CP position (5.9±7.4cm) no longer differed from the one of the controls performing spontaneously (5.0±3.1cm). When the healthy controls executed the task with an asymmetrical foot condition, the results revealed lateral deviations of the CP towards the dominant side in the range of those observed with the patients in the spontaneous foot placement.
Conclusions: As shown previously with weight-bearing distribution, this study revealed that the CP profile is greatly affected by the foot position during the sit-to-stand transfer, mainly around seat-off. From the CP position relative to the base of support, one might infer that, in addition to increasing the symmetry of weight-bearing, rising from a chair with the paretic foot placed behind the non-paretic foot does not increase the risk of falling laterally in individuals with stroke. However, a more complex model of dynamic stability would need to be applied to the sit-to-stand task to support this last finding.

SP-25

Compensatory stepping in response to postural perturbation in a group of working-age, unilateral, transtibial amputees

T. Pauley[1], M. Devlin[2], G.R. Fernie[3] and B.E. Maki[1]

[1]Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada, [2]Department of Physiatry, West Park Healthcrare Centre, Toronto, ON, Canada and [3]Toronto Rehabilitation Institute, Toronto, ON, Canada

Introduction: Impaired balance is common in lower-extremity amputees. As many as 20% of amputees fall during inpatient rehabilitation and up to 50% fall during the first year of transition to the community. While postural sway has been investigated in lower-extremity amputees, little attention has been paid to balance-recovery reactions. This study aims to investigate and compare compensatory stepping reactions in a group of working-aged subjects with unilateral, below-knee amputation and a group of age- and gender-matched controls. The investigation will focus on the stepping strategies used to deal with the tendency of amputees to stand with weight asymmetrically distributed between the prosthetic and intact limbs, the inability to control plantarflexion torque in the prosthetic limb and the loss of proprioception. We will also investigate changes in the attentional demands of controlling the stepping reactions in the amputees.

Methods: In an initial pilot study, three unilateral, below-knee amputees underwent 35 platform-translation perturbations in the antero-posterior (a-p) and medio-lateral (m-l) directions, in order to determine the minimum perturbation magnitude required to elicit a step. The main study involves 12 unilateral, below-knee amputees (35-55 years) and 12 control subjects. Each subject undergoes 92 a-p and m-l perturbation trials delivered in random order. In 20 of these trials, subjects stand with symmetrical weight distribution at the start of the trial. Another 20 trials involve asymmetrical weight distribution (65% on intact limb), as is commonly observed among unilateral, lower-limb amputees. A further 20 trials are completed with the addition of a concurrent cognitive task (using one hand to perform a visuomotor pursuit tracking task). Onset of significant error in tracking performance, subsequent to perturbation onset, is inferred to reflect switching of attention from the tracking task to the balance-recovery task. To investigate modulation of stepping responses in the presence of an environmental constraint, an additional 32 trials that include an obstacle are conducted under both cognitive-task and weight-distribution conditions. Temporal and spatial features of the stepping reactions are characterized using a 6-camera motion-analysis system, force plates and surface electromyography.

Results: Pilot testing revealed that the perturbation magnitudes required to evoke a stepping response in amputee subjects were similar to that required in healthy controls. In addition, the amputee pilots demonstrated a preference for stepping with the intact leg. The results of the main study, currently in progress, will be presented at the meeting.

Conclusions: We anticipate that the findings will inform improved approaches to amputee rehabilitation, and may ultimately help to prevent falls and related injuries and enhance quality of life and occupational productivity. Funding: Workplace Safety and Insurance Board (Ontario).

SP-26

Intersegmental coordination while walking on inclined surfaces: age and ramp angle effects

J.W. Noble and S.D. Prentice

Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: In order to walk on inclined surfaces successfully, the position and orientation of the lower limbs must be controlled. Intersegmental coordination during walking has been described by a planar co-variation law where the segment elevation angles co-vary within a plane [1]. This pattern has been observed for various walking tasks, such as walking at different speeds, walking backwards and turning [1-3]. For all of these conditions the walking is pattern is constrained to level ground, and to a healthy young adult population. The goal of this study was to investigate the degree of intersegmental coordination while walking up ramps and to determine what effect aging may have on this coordination.

Methods: Kinematic data were collected on 5 young and 5 older adults (females, mean age = 23 & 78) during level walking and while walking up ramps ranging in inclination from 3° to 12°. Segment elevation angles were determined for the first complete step on the ramp. Principal Component Analysis (PCA) was used to establish the amount of co-variation of the segment elevation angles [1], and a planarity index (PI) was calculated for each ramp condition [4]. A repeated-measures two-way ANOVA was carried out on relevant variables to determine statistical significance.

Results: All of the participants were able to complete all ramp conditions. The PI showed that the participants had a very high level of planar co-variation across all conditions (>97%) however it was found that the ramp incline had a significant effect on the PI with higher ramp angles leading to a decrease level of planarity ($p = 0.0004$). It was also observed that the orientation of the plane was different between conditions, with the higher ramp conditions resulting in a greater variation in the thigh-shank plane. It was observed that there was no age effect for PI or orientation of the plane.

Conclusions: In order to accommodate the ramp, there are changes required in intersegmental coordination. This resulted in a change in the orientation of the best-fit plane in the planar covariance analysis. Both the older adults and the younger group were able to adapt to the ramp, and alter the coordination of the limb to achieve a high level of planarity in the limb elevation angles. There was a significant decrease in the PI as the ramp angle increased; this appeared to be a deviation from a normal walking pattern that was required to match the elevation angle of the foot to the angle of the ramp during late swing. Planar co-variation of segment elevation angles appears to be maintained while walking up inclined surfaces, although the level of planarity decreases as the ramp angle increases. There was no difference in the planar co-variation between the older and younger groups. 1. Borghese NA et al. J Physiol 1996 494:863-79 2. Grasso R et al. J Neurophysiol 1998 80:1868-85 3. Courtine G et al. J Neurophysiol 2004 91:1524-35 4. Hicheur H et al. J Neurophysiol 2006 96:1406-19

SP-27

Influence of footwear characteristics on dynamic balance control

S.D. Perry[1], C.E. Tschirhart[1] and A. Aqui[1]

[1]Kinesiology & Physical Education, Wilfrid Laurier University, Waterloo, ON, Canada and [2]Toronto Rehabilitation Institute, Toronto, ON, Canada

Introduction: The primary interface between humans and their environment is the foot and/or footwear. Therefore footwear characteristics could potentially have a dramatic effect on the ability to sense and generate balance reactions. Recent studies have linked footwear type and falls in older adults. This highlights the importance of the neuromechanical role of footwear in dynamic balance control.

Methods: Eight young healthy adults (20-26 yrs, Ht. 1.6-1.98 m, Wt 55-82 kg) participated in this study. Participants wore modified footwear that were specially designed to permit variations to heel counter stiffness (minimal, standard & rigid) and midsole material hardness (soft, standard & hard). Transverse plane motion of the center of mass (COM) was calculated using a seven-segment model and right and left foot placement were recorded using a three-dimensional OptoTrak motion capture system (NDI, Waterloo, Canada). The participants were asked to perform crossover stepping gait. During each step the participants were asked to place the swing leg as far laterally as possible across the front of the stance leg. Comparisons between the three levels of footwear modifications were possible because while one characteristic was changed the other was kept constant at the standard level. Analysis involved determining how close the COM approached the foot marker of the crossover leg in the transverse plane. A repeated measures ANOVA was used to determine the difference between the more (rigid or hard) or less (minimal or soft) then standard condition versus the standard condition.

Results: The minimal heel counter stiffness condition resulted in a larger difference ($p<0.05$) between the COM position and the crossover foot when compared to the standard heel counter stiffness. Standard and rigid conditions resulted in approximately the same difference between the COM and the crossover foot placement. The modifications to midsole material hardness had no effect on the position of the COM relative to the crossover foot placement.

Conclusions: The reduction in heel counter stiffness was countered by not shifting the COM as far towards the crossover leg when that leg was placed down in a position lateral to the stance leg. This may be due to the reduction in support of the stance foot because of the minimal heel counter stiffness. In contrast, the modifications in midsole hardness did not result in any noticeable change in this measure. This may suggest that an intact balance control system may be able to adapt to the modifications in midsole hardness but not to changes in the heel counter stiffness during this voluntarily invoked perturbation to gait.
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SP-28

Arm swing and walking velocity in healthy adults

M.P. Ford, S. Garner and J. Kiel

Physical Therapy, University of Alabama at Birmingham, Birmingham, AL, USA

Introduction: Human walking is a complex motor skill involving velocity dependent coordination patterns between the upper and lower body. These patterns are flexible as walking velocity is maintained when arm motion is constrained by a separate motor skill (Eke-Okoro et al., 1997), or trunk motion in altered as a result of added mass from a backpack (LaFiandra et al., 2003). Eke-Okoro et al (1997) reported greater increases in stride frequency, while LaFiandra et al (2003) reported increases in stride length in response to constraints on upper body motion. The purpose of this study was to assess the changes in both upper and lower body motion related to different severities of arm constraint.

Methods: 15 healthy adults, ages 19-55, participated in this study. Each walked across a 30 ft walkway at a self determined comfortable walking velocity under 4 conditions:1) no arm constraint 2) R arm modified constraint – forearm and upper arm strapped together in elbow flexion with motion allowed at the shoulder; 3) R arm fully constained – forearm and upper arm strapped across the trunk with no motion allowed; 4) both arms constrained – both arms strapped across the thorax. R and L arm swing, transverse thoracic rotation, transverse pelvic rotation, cadence, stride length, and walking velocity were determined across 3 walking trials for each condition. The arm data were normalized to arm length, while other dependent measures were normalized to leg length. Effects were evaluated with a within groups ANOVA with repeated measures and a Bonferroni pos-hoc test was used to detect differences between constraint conditions.

Results: There were no significant differences in cadence, stride length, or walking velocity across constraint conditions. Left arm swing did increase slightly with increasing right arm constraint; however the differences were not statistically significant. Transverse thoracic rotation was greatest when both arms were constrained. There were no differences between moderate and fully constrained condition, although transverse thoracic rotation of each was greater as compared to the no constraint condition. Transverse pelvic rotation decreased with increasing arm constraint. There was significantly less pelvic rotation when the R arm was fully constrained and both arms were constrained in comparison to no arm constraint.

Conclusions: The results of the present study demonstrate the adaptability of, and coordination between upper and lower body movement patterns during walking. Similar to previous findings (Ford et al., 2006), limited arm swing was accompanied by slight increases in arm swing on the opposite side. This increase, along with increased transverse thoracic rotation may be attempts to maintain coordination with lower body motion when walking at a comfortable velocity (see LaFiandra et al., 2003). Future study should examine adaptive changes in coordination with different severities of arm constraint at slow, comfortable, and fast walking velocities.

SP-29

The inverted pendulum model accurately estimates ankle stiffness and postural stability borders during heel-toe rocking

C.D. Murnaghan and S.N. Robinovitch

School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada

Introduction: The inverted pendulum model has been used to describe the dynamics of balance maintenance during quiet stance (Winter et al., 1998), grasping (Lee & Patton, 1997), and recovery from postural perturbations (Robinovitch et al., 2002). In the current study, we examined the applicability of this model for describing the mechanics of balance maintenance during voluntary swaying of the COG in the sagittal plane (heel-toe rocking). We focused specifically on determining (1) the accuracy of the model in describing the effect of rocking frequency on postural stability borders, and (2) whether ankle stiffness during rocking could be accurately predicted from the rocking frequency and model's equation of motion.

Methods: Fifteen women (mean 23.0 yrs, SD 2.6) participated in trials where they were asked to rock forward and backward, rotating at the ankles, while keeping the knees and hips extended. Participants were instructed to rock to the extremes of stability in time to a metronome at 0.33 Hz or 0.66 Hz. We acquired the location of the COG using anthropometric techniques (Winter, 2004), and measured the experimental ankle stiffness as the linear slope of the ankle torque versus the angle between the vertical and the COG. We then input experimental values of peak ankle torque (Tmax), moment of inertia (I), rocking frequency (ω), and COG height (L) into our model equations to predict the maximum COG amplitude [COGmax = L*(Tmax + Iω^2 * θmean)/(Iω^2 + mgL)] and ankle stiffness [k = ω^2I + mgL] at each frequency.

Results: The measured COGmax averaged 11.9 cm (SD 1.6) at 0.33 Hz, and decreased to 9.2 cm (SD 1.2) at 0.66 Hz. Model predictions of this parameter averaged 11.9 cm (SD 1.3) at 0.33 Hz (accurate to within 0.1%, on average), and 9.0 cm (SD 1.2) at 0.66 Hz condition (accurate to within 2.9%). The measured subject-specific ankle stiffness based on the full range of torque-rotation data averaged 687 Nm/rad (SD 118) at 0.33 Hz, and 1304 Nm/rad (SD 203) at 0.66 Hz. When data were omitted corresponding to the outer quartiles of displacement (where stiffness varied nonlinearly), this slope increased to 787 Nm/rad (SD 156) at 0.33 Hz, and 1689 Nm/rad (SD 243) at 0.66 Hz. Model predictions provided a strong match to the latter, averaging 788 Nm/rad (SD 152) at 0.33 Hz (accurate to within 0.01%), and 1637 Nm/rad (SD 296) at 0.66 Hz (accurate to within 3.4%).

Conclusions: Heel-toe rocking represents an idealized COG-displacing activity that nevertheless may mimic the essential dynamics governing balance maintenance during activities such as reaching. The dynamics of this task are simulated remarkably well by the inverted pendulum model, as evidenced by (1) the accuracy of the stiffness equation in describing the measured torque-rotation behaviour of the ankle, and (2) the ability of the model to predict the effect of movement speed on postural stability borders. These results encourage the development of more comprehensive assessments and corresponding mathematical models based on this task.

SP-30

Modeling of multi-joint postural control based on kinematic and EMG data

T. Kiemel, A.J. Elahi and J.J. Jeka

Department of Kinesiology, University of Maryland, College Park, MD, USA

Introduction: From a control theory perspective, the postural control system consists of two processes: the mapping from muscle motor commands to sway (the plant) and the mapping from sway to muscle motor commands (feedback), where we consider rectified EMG activity as an proxy for muscle motor commands. Using a linear approximation, each of these mappings can be characterized by an open-loop frequency-response function (FRF). Fitzpatrick et al. (1996) used sensory (galvanic) and mechanical perturbations to identify the plant and feedback FRFs based on a single-joint (ankle) model of the body. We extended this method by using visual perturbations to identify the plant FRF assuming a double-joint (ankle and hip) model of the body. We then used the identified plant FRF to develop a mechanistic multi-joint model of the plant.

Methods: Subjects stood surrounded by front, left and right screens simulating a visual scene rotating about the axis through the ankles. The rotation signal consisted of ten sinusoids ranging in frequency from 0.024 to 2.936 Hz. Trunk and leg angles in the sagittal plane and rectified EMG signals from soleus, gastrocnemius, tibialis anterior, rectus femoris, biceps femoris, erector spinae and rectus abdominus muscles were analyzed. We computed closed-loop FRFs from visual scene position to each segment angle and EMG signal.

Results: The gain from visual scene position to EMG activity were qualitatively similar for all muscles. Cophases were similar across frequency for all posterior muscles and for all anterior muscles. Cophases for posterior and anterior muscles differed by approximately 180 degrees. Given this roughly fixed relationship between muscle activity across frequency, we modeled the plant as having a single input. The input was the weighted sum of all EMG signals, with posterior and anterior muscles assigned positive and negative weights, respectively. Cophases from visual scene position to the leg and trunk angles were similar at low frequencies and approached a difference of 180 degrees at higher frequencies. Therefore, we considered leg and trunk angles as separate plant outputs. We identified the SIMO (single-input multiple-output) plant by dividing the the FRFs from visual scene position to segment angles by the FRF from visual scene position to combined EMG activity. We modeled the plant using a two-joint (ankle and hip) model of the body and a second-order low-pass transfer function for the mapping from EMG activity to joint torques.

Conclusions: The plant model was in general agreement with the empirically identified plant FRF. We are currently combining the plant model with various models of feedback. In these posture models, the change in leg-trunk coordination across frequency is due to properties of the plant and are not produced by the feedback control strategy. Supported by NIH grants RO1NS35070 and RO1NS046065.

SP-31

DYNAMIC SIMULATION OF THE BEHAVIOR OF AN ORTHOSIS FOR KNEE AND ANKLE FUNCTIONAL COMPENSATION DURING GAIT

A. Cullell, J. Moreno and J. Pons

Industrial Automation Institute-IAI, Madrid, Spain

Introduction: An intelligent orthosis for knee and ankle joints functional compensation has been developed in the frame of the European project Gait (EU contract IST-2001-37751). Such a device can be worn by patients with an abnormal gait caused by muscle weakness due to neurological and muscular diseases in order to provide safety and walking pattern improvement. The idea under the design of this system was to approach the behavior of each joint, knee and ankle, as a linear elastic spring, constructing an actuating system to be the substitute of the real muscles. According to this approach, different springs will provide the needed actions for each joint. Selection of those springs is done based on two parameters, patient's weight and walking speed, and according to the hypothesis that joint angles will be similar during gait for a patient wearing the orthosis and for normal subjects. To evaluate this hypothesis it was necessary to test the concept previously with a computer model. This paper

presents the computer model with all assumptions and simplifications used in order to simulate the behavior of the orthosis-leg system during the gait cycle.
Methods: Software used for the simulation was ProEngineer Wildfire 2.0. The orthosis was modeled as a mechanism formed by different bodies with the same kinematic relationships as the real orthosis. The leg was modeled as a passive mass consisting of three bodies, thigh, calf and foot, being each one rigidly attached to the corresponding part of the orthosis. Steel, aluminium, and carbon fiber densities were considered for the orthosis, and a density of 950 Kg/m3 was considered for the patient leg. All bodies were supposed to be rigid. In order to model the actuators, elastic constants of the active springs in each case were introduced. In addition, in order to simulate the performance of the system during gait cycle, stance and swing were studied separately. Stance movement was divided into three phases, considering two or three degrees of freedom depending on simulation conditions. Hip angle, knee angle and foot angle with the floor were used as DOF's, being the last one restricted while the foot leans completely on the floor. Data from hip horizontal and vertical reactions and torque applied were used as inputs. Swing movement was split into two phases, the system was supposed to have three DOF's (Hip, knee, and foot angles), and the hip position was fixed. Torque applied on the hip was used as input.
Results: Despite some differences with the theoretical gait pattern, kinematic and dynamic results showed that the hypotheses and simplifications used during the design of the actuating system are valid. Moreover, the model was revealed as a useful tool in order to adapt the constants of the springs in the orthosis to each patient since different values can be evaluated.
Conclusions: The developed computer model can also be used as starting point for future computer simulations of gait cycle, with or without orthotic devices.

Cognitive Influences on Posture and Locomotion

SP-32

Exploring the process interference between balance control and working memory by an event-based analysis of body sway microstructure

L. Johannsen and A.M. Wing

Behavioural Brain Sciences Centre, University of Birmingham, Birmingham, UK

Introduction: Previous studies have demonstrated interactions between balance control and cognitive processes. However, simultaneous cognitive load does not always impair stability of balance. Possible causes for this inconsistency of effect include uncontrolled performance trade-offs between the two task domains and possible confounding between difficulty and process complexity of the cognitive task.
Methods: The present study develops a new methodological approach to avoid these issues by analysing the microstructure of body sway related to immediately preceding stimuli in a concurrent cognitive task. While standing with eyes open in narrow base stance, 10 adult volunteers were tested in single and dual-task mode. In the dual-task condition, subjects performed a sequential 1-item numerical memory updating task presented on a computer screen. The difficulty of this cognitive task was parametrically varied by adaptively adjusting the exposure time to define a performance operating characteristic for each subject. In order to keep performance trade-off constant across difficulty levels, the difficulty level for each following trial was selected at random. Participants' ground reaction forces were registered using Bertec forceplate to yield centre of pressure (CoP). Postural "threat" at each point in time was calculated from CoP using the estimated time-to-contact (TtC) the stability boundary. State-dependent intervention by the balance control system was represented as increasing TtC rate (dTtC). Assuming that the effect of any intervention of the balance control system varies in time, the direction specific dTtC distributions were determined. For segmented regions within the stability boundaries, differences in the dTtC distributions were calculated as a function of the dual-task condition and the level of postural threat.
Results: Preliminary analysis of the data from a single subject revealed that, in the single task condition, close to the stability boundary the dTtC distribution was skewed towards the central point (directionally specific balance adjustments). In contrast, in the central region of the stability range, the dTtC distribution was directionally non-specific, indicating reduced levels of postural intervention. There was no difference between the single task and dual-task conditions in the dTtC distributions for the central region but a difference was apparent in the region close to the stability boundary. Its dTtC distribution lost directional specificity under dual-task condition indicating the involvement of working memory resources in state dependent postural adjustments.
Conclusions: Event-based analysis of sway microstructure thus provides a means of demonstrating that concurrent cognitive demands on working memory affect the distributions of direction specific TtC adjustments. We interpret our results in terms of competition between balance and cognition for processing resources involved in the planning and execution of balance adjustments.

SP-33

Spinal postures in sitting: can researchers and subjects differentiate postures at lumbar and thoraco-lumbar regions?

A. Claus[1], J. Hides[1], L. Moseley[2] and P. Hodges[1]

[1]*Physiotherapy Division, The University of Queensland, Brisbane, QLD, Australia and* [2]*Department of Physiology, Anatomy and Genetics, University of Oxford, Oxford, UK*

Introduction: Since the 1950's an 'ideal' spinal posture in standing was proposed to involve a slight lordosis at the lumbar and slight kyphosis at the thoracic spine. These spinal curves have also been advocated clinically as an 'ideal' sitting posture. Surface measures of spinal posture lack a clear standard for methodology, and few studies have quantified spinal curves in upright postures. Our first objective was to quantify sagittal spinal curves in sitting, using surface measures at thoracic, thoraco-lumbar and lumbar spinal regions. Our second objective was to determine whether healthy subjects could perform the 'ideal' spinal posture in sitting, and differentiate it from the other upright postures.

Methods: Ten healthy male subjects had 3-D electromagnetic tracking system sensors adhered to the skin overlying spinous processes at T1, T5, T10, L3 and S2 (for sensor attachment subjects were supported in prone lying, flat from T5 to S2). With the subjects in sitting, sagittal spinal curves were represented by angles between segments at T1-T5 and T5-T10 (thoracic), T5-T10 and T10-L3 (thoraco-lumbar), T10-L3 and L3-S2 (lumbar). Four sitting postures were tested; slumped, flat, thoraco-lumbar lordosis and the clinical 'ideal' lumbar lordosis with thoracic kyphosis (defined by thoraco-lumbar and lumbar angles). Two intervention conditions were used. First, subjects imitated pictures of each posture, to test whether they intuitively differentiated the spinal curves. Secondly, subjects were given feedback and manually facilitated, to test physical capability of performing the flat, thoraco-lumbar lordosis and the clinical 'ideal' lumbar lordosis posture. Postures were performed in random order, with data recorded (100 Hz) for 15 s. Data were extracted for one full respiratory cycle (~ 4 s), angles were calculated in Matlab, and averaged over three trials for each posture, intervention condition and subject. Angles for each spinal region were compared between postures and intervention conditions with repeated measures analysis of variance.

Results: Subjects were able to imitate postures with the same curve direction at thoraco-lumbar and lumbar regions of the spine (slumped, flat or thoraco-lumbar lordosis), but did not intuitively differentiate the clinical 'ideal' lumbar lordosis posture from flat (lumbar angle $p = 0.14$) unless feedback/manual facilitation were provided (lumbar angle $p < 0.01$).

Conclusions: The methods developed for this study allowed quantification of spinal posture. Subjects could not perform the clinical 'ideal' spinal posture of lumbar lordosis with thoraco-lumbar kyphosis in sitting without feedback/manual facilitation. This finding implies that further clinical trials and biomechanical evaluation of these different upright sitting postures is warranted, to determine if such feedback/facilitation is worthwhile.

SP-34

Cognitive-motor interference during walking in people after stroke

P. Plummer D'Amato[1], L. Altmann[2], A.L. Behrman[2] and M. Marsiske[2]

[1]University of California Los Angeles, Los Angeles, CA, USA and [2]University of Florida, Gainesville, FL, USA

Introduction: Studies of cognitive-motor interference during walking in people after stroke have demonstrated that concurrent performance of a cognitive task and walking can produce a decrement in both. Various theoretical accounts for cognitive-motor interference have been offered, but it remains unclear whether specific types of cognition are related to particular gait parameters. The purpose of this study was to explore whether the interference effects in gait and cognition varied depending on the type of concurrent cognitive task that was presented.

Methods: Thirteen individuals post stroke with a mean age of 60.5 years (SD 15.3) participated in this study. Subjects performed a walking task alone (single task walk) and in combination with each of the three cognitive tasks (dual task conditions): auditory 1-back (a working memory task), modified clock task (a visuospatial decision task), and spontaneous speech production. To determine the dual task effect on cognition, the cognitive tasks were also performed without concurrent walking (i.e. seated). Gait data were acquired continuously for approximately 3 minutes, which was the average amount of time it took to complete the cognitive tasks. Footswitches worn inside the subjects' shoes were used to record temporal gait events (heel strike and toe off). To avoid complicating the walking task with repeated turns, subjects walked around an indoor oval track (27.5 m). Cognitive tasks were presented as auditory stimuli, which were delivered via wireless headphones; a wireless microphone recorded subjects' verbal responses ("yes" or "no"). Subjects' verbal responses in the speech task were recorded using a digital recorder. With regard to locomotion, the variables of interest were gait speed, stride time, stride time variability, average stride length, and cadence. Response latency and accuracy were measured for the 1-back and modified clock task. Speech samples were analysed on a number of dimensions of language.

Results: Significant dual task effects were observed for gait speed, stride time, average stride length, and cadence, but not for stride time variability. The largest effects on gait occurred during the speech task. The 1-back task produced the least gait interference, but the differences between the three dual task conditions were statistically significant only for gait speed. The only dual task effect on cognition was in the speech task (no effects for the clock or 1-back tasks). Compared to the single task condition, narratives in the dual task condition had more pauses and fewer words and utterances. There was no effect on other language metrics, such as sentence length, number of fillers or ums/ahs, sentence complexity, and grammaticality.

Conclusions: The observed effect on gait parameters suggests that the subjects in this study may have placed a higher priority on the performance of cognitive tasks. For these subjects, speech appears to interfere with gait more than working memory and visuospatial cognitive processes.

SP-35

Modelling attentional influence on postural control in young and older adults

A. Mahboobin[1], P. Loughlin[1] and M.S. Redfern[2]

[1]Electrical Engineering, University of Pittsburgh, Pittsburgh, PA, USA and [2]Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: A postural control model (Fig. 1), which includes sensory integration and a time delay, was applied to postural sway data from young and older adults during dual-task experiments, to quantify the influence of attention on postural control. We hypothesized that performing information processing (IP) tasks during postural challenges would interfere with sensory integration and processing for postural control, manifest as an increase in the postural control time delay of the model when fit to the data. We further hypothesized that this effect would be greater in older adults.

Methods: Dual-task experiments involving IP tasks concurrent with postural perturbations were conducted, and data from ten healthy young adults (25±3 yrs.) and five older adults (73±9 yrs.) were analyzed. Subjects stood with eyes closed, while performing IP tasks, on an EquiTest posture platform that rotated randomly (± 1 deg) for 121 sec about an axis collinear with the ankle axis. Three trials per task were conducted. IP tasks were performed on different days; subjects trained on tasks prior to testing. IP tasks were: 1) None, 2) an auditory choice reaction task (CRT), in which subjects pressed a hand-held microswitch depending on whether they heard a high or low tone, and 3) an auditory vigilance task (VT), in which subjects had to remember the number of high or low tones during the trial. Platform movement and A-P hip position were recorded, from which least-squares fits to the postural control model were made (Peterka, J. Neurophysiology, 2002). The time delay estimates from the model fits were then compared across conditions.

Results: In older adults, the postural control time delay increased from a mean of 155 ms (SD 12 ms) with no IP task to 165 ms (SD 20 ms) for the CRT task and 163 ms (SD 12 ms) for the VT task. Young adults exhibited an increased time delay for only the more cognitively-challenging VT task, from a mean baseline of 153 ms (SD 12 ms) to 162 ms (SD 13 ms).

Conclusions: These results suggest that attentional influences on standing balance can be modeled as an increase in the processing time for postural control. Further, older adults appear to be more sensitive to less challenging cognitive tasks (i.e. CRT) compared to young adults. [Funded by the Pittsburgh Claude Pepper Center (NIH/NIA P30 AG-024827)]

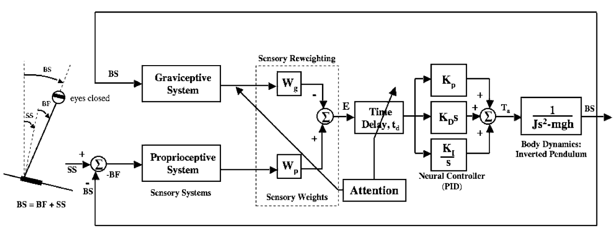


Fig. 1: Postural control model, including influence of attention on sensory processing and integration [adapted from (Peterka, J. Neurophysiology, 2002)].

SP-36

Intentional effects of visual stimulus velocity and postural control in adults

A. Barela[1], N.M. Rinaldi[2], D.R. Toledo[2] and J.A. Barela[2]

[1]UNICSUL, Sao Paulo, SP, Brazil and [2]UNESP, Rio Claro, SP, Brazil

Introduction: The goal of this study was to verify the effects of knowledge about visual surrounding manipulation with different velocities in the coupling between visual information and body oscillation in young adults.

Methods: Twenty undergraduate students with no known musculoskeletal or neurologic impairment were divided in two groups and asked to stand inside a moving room which oscillated at 0.2 Hz. For the low velocity (LV) group, the moving room oscillated with a 0.5 cm amplitude and 0.6 cm/s peak velocity. For the high velocity (HV) group, the moving room oscillated with a 0.9 cm amplitude and 1.0 cm/s peak velocity. Each group participated in seven trials of 60 s, preceded by a single trial with a stationary visual room. In the first three moving trials, participants were instructed to look straight ahead towards a target and they were not aware that the room was moving (normal condition). In the last three trials, participants were informed that the room was moving and were instructed to resist its influence (resist condition). The order of the trials was the same for all participants. Coherence, gain, phase, and mean body oscillation amplitude were calculated.

Results: Gain was higher in the LV than the HV condition. However, in the LV condition, gain was lower in the resist condition than in the normal condition. Phase was different only between conditions; with body oscillation ahead of the moving room oscillation in the resist condition. No difference was found for mean sway amplitude. These results show that when the room moved with low velocity, body sway was more influenced compared to when the room was moved with high velocity. Knowledge about room oscillation did not influence the coupling between moving room and body oscillation for the HV group. On the other hand, knowledge about the room's movement influenced this coupling for the LV group.

Conclusions: These results indicate that intention may play a role depending on the characteristics of the stimuli. When coupling to the stimulus is weak, intention effects are absent whereas when coupling is strong, intention can change the coupling dramatically.

SP-37

How accurate people can place their feet?

Y. Kobayashi[1], Y. Mine[1] and H. Fujimoto[2]

[1]Graduate School of Human Sciences, Waseda University, Tokorozawa City, Saitama, Japan and [2]Faculty of Human Sciences, Waseda University, Tokorozawa, Saitama, Japan

Introduction: Recently, we reported that lateral toe clearances significantly decreased in comparison with the level obstacles while participants stepped over the lateral-high and medial-low tilted obstacles, although no significant differences in lateral and medial toe clearances were seen while the participants stepped over the medial-high and lateral-low tilted obstacles. Moreover, in Japan, many people often stub one's little toe to the edge of door, or the drawer, while walking indoor, and those stubbing sometimes cause fracture of Phalanx. From these facts, we hypothesized that people tend to perceive the position of their feet more medially than actual feet position, and this discrepancy between perceived and actual feet position cause above mentioned decreasing of lateral toe clearances, or stubbing one's little toe to the drawers. Therefore, this study compared the accuracy of foot positioning accuracy between medial edge and lateral edge of our feet.

Methods: To determine the accuracy of foot positioning sense in the means of foot placement, 10 young adults were asked to place either medial edge or lateral edge of their feet along the base line on the floor as close as possible while covering their

lower view, and the edge of placed feet were scanned by using laser displacement gauge. From the collected data, constant error, the distances between the edge of placed feet and the base line on the floor, and absolute error, the absolute distances between the edge of placed feet and the base line on the floor were defined. Collected data were compared in 2 by 2 design, the medial or lateral trials, and dominant leg or in-dominant leg.
Results: The significant differences were found in the constant error between the medial and lateral trials. Even the participants expected that their feet placed along the line, their feet tend to place on the line for the lateral trials, and place away from the line for the medial trials (fig.1). There were no significant effects between dominant and in-dominant legs, and absolute error.
Conclusions: These results indicate that without visual feedback, people tend to expect the position of their feet more medially than actual feet position. This discrepancy between perceived feet position and actual feet position may be one of the reasons of tripping or stubbing our feet to the obstacles while walking.

SP-38

Optimising cueing strategies to improve walking in PD, when on and off medication

K. Baker[1], L. Rochester[1], A. Nieuwboer[2] and D. Burn[3]

[1]School of Health, Community and Education Studies, Northumbria University, Newcastle Upon Tyne, UK, [2]Faculty of Movement and Rehabilitation Sciences, Katholieke Universiteit, Leuven, Belgium and [3]Regional Neurosciences Centre, Newcastle General Hospital, Newcastle Upon Tyne, UK

Introduction: Cues improve walking in PD, however, the effect of cues off medication may differ because of increased attentional demands when walking. Differences in the effect of cue types have been attributed to attentional cost, i.e. whether the cue competes for or reduces attentional resources. Externally generated cues may be more practical, less attentionally demanding and easier to use than internally generated cues in real life situations. This study aims to evaluate 3 cueing strategies during single and dual tasks, on and off medication.
Methods: 15 PD subjects (9M, 6W, age 70±5.37, H&Y rating 2.5 - 3) were evaluated on 2 occasions: once ON medication and once OFF medication (before first morning dose). They were assessed in the home, 2 weeks apart and assessments were counterbalanced. During each assessment subjects performed a functional test; comprising a single task (walk only) and a dual task (walk + carry tray) under the following cueing conditions; (1) stepping to an auditory tone set at preferred step frequency (AUD), (2) an attentional strategy to think about taking a big step (ATT) and (3) an associate cue; stepping to an auditory tone while thinking about taking a big step (AUD+ATT) presented in a random order. Non-cued trials were performed before (BL1) and after (BL2) cued trials. Walking speed, stride amplitude and step frequency were measured using a Stride Analyzer. Repeated measures ANOVA was used to compare the difference between trials and tasks.
Results: ON medication; Walking speed increased compared to BL1 with all cue types (AUD P=0.006; ATT P=0.001; AUD+ATT P<0.001). Step frequency reduced with the ATT cue (P=0.002) but was unaffected by the other cue types. Stride amplitude increased with all cue types (AUD P=0.016; ATT P<0.001; AUD+ATT P<0.001). An improvement in stride amplitude was observed in BL2 (P=0.001). These effects were stable in single and dual tasks. OFF medication; Walking speed increased with the ATT (P=0.001) and AUD+ATT cue (P<0.001). Step frequency reduced with the ATT cue (P<0.001). Stride amplitude improved with the ATT (P<0.001) and AUD+ATT (P<0.001) cue types. Stride amplitude was improved in BL2 (P=0.004). These effects were stable in single and dual tasks.
Conclusions: Walking speed and stride amplitude consistently improved with the attentional and associate cues. The auditory cue was effective in 'on' only. The attentional and associate cues give specific information on stride amplitude. Executive function in PD deteriorates off medication; therefore the subjects may require more specific information from a cue. Interestingly in the off condition it is the associate cue which has a larger effect on walking speed and stride amplitude in the dual task condition which is when attentional resources are in most demand and the ability to appropriately allocate attention at its poorest. The associate cue may be a practical strategy to improve gait parameters during functional walking activities in the home.

SP-39

Independent influence of visual hemineglect on postural control in the acute phase of stroke

A.C. Geurts[1], I. Van Nes[2], S. Van der Linden[1] and H. Hendricks[1]

[1]Dept. of Rehabilitation, Radboud University Medical Center, Nijmegen, Netherlands and [2]Dept. of Research, Development and Education, St Maartenskliniek, Nijmegen, Netherlands

Introduction: It is well known that stroke patients with visual hemineglect have a worse functional outcome compared to those without neglect, partly by affecting postural skills. However, it is still unclear how neglect affects balance in the acute phase of stroke and to what extent the presence of neglect should influence patient management in this phase. Hence, the purpose of this study was to determine the independent contribution of visual hemineglect to impaired postural control in the acute phase (< 2 weeks) of stroke compared to other possible determinants.
Methods: This study was performed in six Dutch hospitals in the region of Nijmegen. A total of 78 patients with an acute supratentorial stroke (mean age 71.6 ± 11.6 years) and post-stroke interval of 5.5 ± 2.4 days was included. Functional balance was measured by the Trunk Impairment Scale (TIS), the Trunk Control Test (TCT), the Berg Balance Scale (BBS) and the Functional Ambulation Categories (FAC). Visual hemineglect was assessed by means of an asymmetry index obtained from the Behavioral Inattention Test (BIT). Patients muscle strength (Motricity Index or MI), somatosensation (vibration sense), sustained attention (elevator counting subtest) and the presence of hemianopia (visual confrontation test) were measured as other possible clinical determinants. To determine the independent contribution of visual hemineglect to balance, stepwise backward multiple linear regression analysis was performed introducing all selected clinical determinants as well as age and time post stroke as important biological determinants.

Results: Visual hemineglect was present in 17 patients (21.8%). Except for the proportion of right hemisphere strokes (88.2% in N+ and 47.5% in N-), no difference was found in age, type of stroke or time post stroke between the patients with neglect (N+) and those without (N-). N+ patients had on average lower scores on all balance assessments, less muscle strength, more severe loss of sensation, poorer sustained attention and suffered more often from hemianopia. However, multivariate linear regression showed that only visual hemineglect, muscle strength and age independently contributed to impaired balance explaining 65.6% of TIS variance, 64% of TCT variance, 72% of BBS variance and 71% of FAC variance. Contraversive pushing was diagnosed in 3 N+ patients with a right hemisphere infarction. These patients tended to suffer from relatively severe neglect (with preserved sustained attention) and showed on average poorer balance scores.
Conclusions: This study showed that visual hemineglect independently contributes to impaired postural control in the acute phase of stroke, equivalent to the effect of a 17% lower leg MI or being 16 years older. Since balance is an important predictor of long-term functional outcome, this result has implications for the management of patients in the acute phase.

SP-40

Postural treatment of post-traumatic disorder

G. Kemoun[2], J. Limongi[1], P. Carette[2], E. Gaudet[1] and N. Floirat[1]

[1]centre de posturologie, Millau, France and [2]rehabilitation department head, CHU la Milétrie, Poitiers, France

Introduction: The interconnections between phobic disorders, anxiety and postural anomalies have already been clearly established. We have put forward the hypothesis that subjects suffering from post-traumatic anxiety are frightened because they perceive a loss in control of their stability. In order to treat their fear, it would suffice to restore such control. The purpose of our study is to show the interest of postural treatment with regard to post-traumatic anxiety.
Methods: Forty patients having had accidents on the public highway were evaluated by us before and 3 months after the postural treatment by means of foot orthoses on a force platform. Assessment of the relative degree of anxiety was performed by application of the Hamilton Anxiety Rating Scale and on the surface of the statokinesigram.
Results: Before treatment Subjects with Low anxiety and N A = 04, subjects with High anxiety and A A = 36 Total 40 After treatment Subjects with Low anxiety and N A = 37, subjects with High anxiety and A A = 03 Total 40 N A = Normal area (= 91 mm Eyes opened - = 222 mm Eyes Closed A A = Abnormal area(> 210 mm Eyes opened - > 600 mm Eyes Closed)
Conclusions: The impressive therapeutic success rate (91%) indicates that post-traumatic anxiety may be significantly mitigated by treatment of the postural disorder. It would seem that by heightening proprioceptive afferences, foot orthosis provides supplementary postural information liable to reestablish balance among the circuits regulating posture, circuits that are to some extent common with those of memory.
results before treatment

low anxiety	normal area eyes opened 4	abnormal area eyes opened 0	total 04
high anxiety	normal area eyes opened 0	abnormal area eyes opened 36	total 36

SP-41

Cognitive and postural effects of the trace of an unresolved traumatic emotional episode

N. Floirat[1], J. Limongi[1], P. Carette[2], E. Gaudet[1] and G. Kemoun[2]

[1]centre de posturologie, Millau, France and [2]rehabilitation department head, CHU la Milétrie, Poitiers, France

Introduction: We admit that the postural regulation system in normal subjects classically yields anterior displacement of the center of pressure (CoP) in close-eyed (CE) as opposed to open-eyed conditions. The connections between thymo-cognitive factors and postural disorders have been clearly established. The purpose of our study is to show that individuals having undergone a traumatic emotional episode, even long ago, undergo posturographic modifications involving posterior displacement of their CoP under CE measurement conditions.
Methods: A prospective study of 100 consecutive patients having consulted on account of chronic aches of the locomotive apparatus. All of them benefited from recordings on a force platform and then from a semi-directive interview meant to perceive their psycho-affective history and, more particularly, the existence of a traumatic emotional episode. The interview was performed by a practitioner who had not been apprised of the posturographic results.
Results: On force platform and Antero-posterior axis : Subjects with frontally projected CoP in CE and persistently disturbing emotional episode noted = 04 On force platform and Antero-posterior axis : Subjects with frontally projected CoP and absence of a persistently disturbing emotional episode noted = 67. Total = 71 On force platform Antero-posterior axis : Subjects with backwardly projected CoP in CE and persistently disturbing emotional episode noted = 27 On force platform Antero-posterior axis : Subjects with backwardly projected CoP in CE and absence of a persistently disturbing emotional episode noted = 02. Total = 29 Total general = 100
Conclusions: Under close-eyed test conditions, the subjects affected by persistence of the unconscious trace of an unresolved emotional episode see their pressure center pushed backwards in comparison with the positioning of this center under open-eyed test conditions. Such postural behavior may be likened to true phobic avoidance. Suppression of visual information under CE conditions favors the vestibular passages of which the interconnections with the limbic system and the tonsil and consequently with thymo-cognitive information have been duly noted. This posturographic sign thereby appears quite liable to indicate to therapists the nociceptive action of the trace of the unresolved traumatic emotional episode and the need to detect and treat the latter.

SP-42

Changes in activity at the cerebral cortex associate with the optimization of responses to external postural perturbations when given prior warning

J.V. Jacobs[1], F.B. Horak[1], K. Fujiwara[2], H. Tomita[2], N. Furune[2] and K. Kunita[3]

[1]Neurological Sciences Institute, Oregon Health & Science University, Beaverton, OR, USA, [2]Human Movement and Health, Kanazawa University, Kanazawa, Japan and [3]Institute for Health and Sport Sciences, Osaka City University, Osaka, Japan

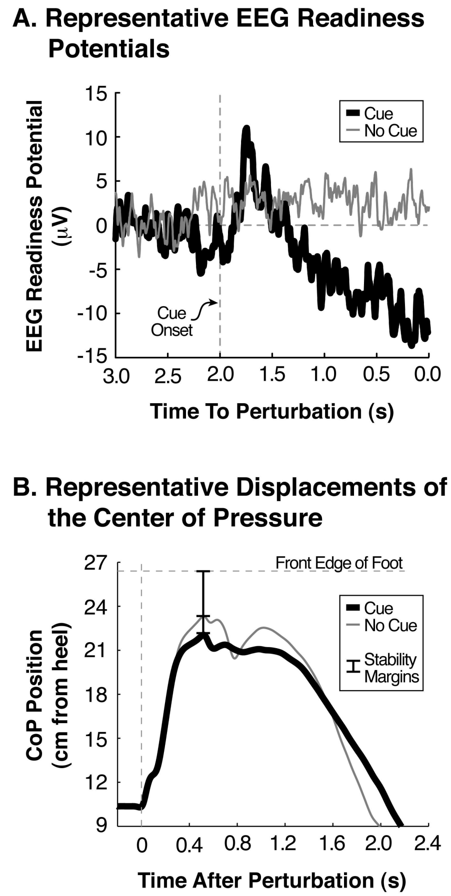
Introduction: Many cortically mediated contexts (such as anticipation) affect responses to external postural perturbations. We sought to determine whether modulation of cortical activity before a postural perturbation mediates the modification of responses associated with prior warning of the perturbation.

Methods: Twelve healthy human subjects (21-32 years of age) responded with their feet in place to expected backward translations of a force platform under their feet. To alter the predictability of the perturbations' onset, the subjects performed 40 trials with and without a visual warning cue that turned on 2000 ms before perturbation onset (the Cue and No Cue condition, respectively). Cortical readiness potentials were recorded by electroencephalography (EEG) for 3000 ms prior to the translation. We defined cortical modulation as the effect of cue condition on the peak amplitude of the readiness potential. We defined response modification as the effect of cue condition on stability margins: the maximum induced forward displacement of the body's center of pressure, relative to the front limit of the base of support, as recorded by the force platform under the subjects' feet.

Results: The subjects' average EEG waveforms over the skull's vertex exhibited slow negative displacements (readiness potentials) before the perturbations only in the Cue condition. The peak amplitudes of the subjects' average readiness potentials, as well as the subjects' average stability margins, were larger in the Cue condition than in the No Cue condition (Figure 1). Cortical modulation significantly correlated with the subjects' response modification (Pearson $r = 0.59$; $P < 0.05$).

Conclusions: Activity of the cerebral cortex optimizes responses to expected, externally induced postural perturbations.

Figure 1



SP-43

Postural treatment in postural posttraumatic disorder

N. Floirat[1], J. Limongi[1] and P. Gagey[2]

[1]posturology, posturology consulting, millau, France and [2]posturology, institut de posturologie, Paris, France

Introduction: " We are afraid because we tremble ". This William James's idea helped us to emit the hypothesis that the suffering subjects of a confusion of stress traumatic post disorder are afraid because they become aware that masters her of their postural oscillations escapes them? It would be enough to make them a boss again of their stability to treat

Methods: We measured on platform 21 patients victims of accidents of the public highway in closed-eyed condition, before and after a postural treatment by insoles and we compared by two tables of contingency, the one before, the other one 3 months after the treatment, the importance of the fear and the surface of their SKG.

Results: Results before postural therapy SKG with normal area < 600 mm = 4, SKG with abnormal area > 600 mm = 17. Total = 21 Results after postural therapy with insoles. SKG with normal area < 600 mm = 18, SKG with abnormal area > 600 mm = 3. Total = 21

Conclusions: The important rate of success of the therapy (91 %) indicates that the post-traumatic confusions of stress can be effectively handled by insoles realized by the chiropodists, both at the level of the postural abnormalities and at the level of the fear. This findings does not claim to prove that the suffering subjects of a confusion of stress traumatic post disorder are afraid because they perceive that the mastery of their stability escapes them, but at least it draws the attention on this hypothesis which comes to us of William James's idea, because never anybody aspired that insoles constituted a psychiatric treatment.

SP-44

Methylphenidate improves cognition and reduces fall risk in elderly people with increased fall risk: a single dose, placebo controlled, double-blind study

R. Ben-Itzhak[4], E. Simon[3], N. Giladi[1] and J.M. Hausdorff[1]

[1]Movement Disorders Unit, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel, [2]Departments of Physical Therapy and Neurology, Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv, Israel, [3]Department of Clinical Neuroscience, Neurotrax Corp., New York, NY, USA and [4]Reuth Medical Center, Tel-Aviv, Israel

Introduction: Impaired executive function (EF) and attention have been associated with fall risk and gait instability, especially while dual tasking during walking. Improved cognition may reduce this dual tasking effect and reduce fall risk. The objective of the present study was to test the hypothesis that a single dose of methylphenidate (MPH) enhances usual walking stride and swing time variability (markers of fall risk), improves cognitive function, and reduces the deleterious effect of dual tasking on gait stability.
Methods: A randomized, double-blind, placebo-controlled, crossover study was conducted in 17 non-demented patients (mean age: 75 years) with increased fall risk. Gait and cognitive function were evaluated before and two hours after a single dose of MPH (20 mg) or placebo, in two sessions separated by 1 - 2 weeks.
Results: MPH treatment significantly improved (reduced) stride time variability and swing time variability, both during usual walking and when subjects walked while performing serial 3 subtractions (dual tasking). For example, in response to MPH, swing time variability decreased from 4.4±0.9% to 3.9±0.7 % during usual walking (p=0.047) and from 6.8±2.5% to 3.7±0.5% during serial 3 subtractions (p=0.002). The placebo did not significantly effect stride time or swing time variability during usual walking or during dual task walking. MPH also significantly improved EF (from 88.9±2.6 to 95.7±2.3; p=0.001) and attention (from 86.1±4.4 to 99.8±2.8; p=0.006), while having no effect on memory (p=0.92). Improvement in EF in response to MPH correlated with improvement in gait variability (e.g., r=0.60; p=0.015 for usual walking swing time variability and r=0.77; p=0.001 during serial 3 subtractions).
Conclusions: These results demonstrate the potential of using cognitive-enhancing pharmacologic agents to improve gait and reduce fall risk.

SP-45

Performing a working memory task while walking on a treadmill: Lifespan differences in cognitive-sensorimotor dual-task dynamics

S. Schaefer, M. Lövdén, B. Wieckhorst, A. Pohlmeyer, J. Verrel and U. Lindenberger

Max Planck Institute for Human Development, Berlin, Germany

Introduction: We found age-differential interactions between gait variability and cognitive load when young and older adults were performing a working memory task with increasing levels of complexity while walking on a treadmill. Young adults decreased the variability in some gait parameters with increasing cognitive load, whereas older adults showed increasing gait variability when cognitive load was high (Lövdén, Schäfer, Pohlmeyer, & Lindenberger, submitted). Similar findings have been obtained in the domain of balance performance (Huxhold, Li, Schmiedek, & Lindenberger, 2006).
Methods: To extend the study of age differences in gait adaptation to children, we extended the treadmill paradigm to 9-year old children. The sensorimotor task consisted of walking on a treadmill with a self-chosen comfortable speed that remained constant across experimental conditions. As a cognitive task, we used the n-back task, in which people indicate whether a number is the same as the number presented previously (1, 2, 3, or 4 positions back, depending on the working memory load condition). Spatio-temporal gait parameters were measured with a motion capture system (12 infrared cameras, Vicon Motion Analysis system).
Results: We used a standardized coefficient of gait variability controlling for the influence of body height as the dependent measure in the walking task. When walking on the treadmill without any cognitive challenge, across-stride variability of several gait parameters, such as gait velocity, stride time and stride length, was higher in children than in older adults, who in turn showed higher variability than young adults. Concerning the influence of the concurrent working memory task, children showed a similar pattern as older adults, that is, increasing gait variability with increasing cognitive load. Results indicate that children and old adults show a less regular and potentially less stable gait when cognitively challenged, whereas young adults show a more regular gait.
Conclusions: Concerning cognitive performance, young adults outperformed children and old adults. Surprisingly, we observed significant performance improvements in the cognitive domain under dual-task relative to single-task conditions: Participants had higher scores in the cognitive task when concurrently walking on the treadmill than when sitting on a chair. This effect was stronger in children and young adults than in old adults, perhaps reflecting closer-to-optimal arousal levels for children and young adults under dual-task conditions. Future studies need to find out whether the enhancement effect is absent in older adults because walking requires more cognitive resources, because the optimal cognitive performance requires less arousal, or both.

SP-46

The effect of attentional distraction on muscle activity during stance and late swing phase of gait

R.G. DeMont[2], S.A. Fraser[1], K.Z. Li[1] and V.B. Penhune[1]

[1]Psychology, Concordia University, Montreal, QC, Canada and [2]Exercise Science, Concordia University, Montreal, QC, Canada

Introduction: This study evaluated muscle activation under conditions of attention distraction to determine the influence of distraction on lower extremity motor control. Previous research has used a pre-activation (Pre-A; 150 ms prior to heel strike) measure as a contributory facet of joint stability. Pre-A and stance muscle activity are important factors in understanding falls which could increase due to deficits in functional ability in attention distracted individuals. We compared single task walking to dual task walking with auditory words judgment in older and younger groups.

Methods: Subjects (N = 48, 18-35 years and 60-80 years) walked at a self selected speed on a treadmill and performed a semantic judgment task. Muscle activation (Pre-A and stance) was measured using EMG from 8 muscles (VMO- vastus medialis oblique, VL-vastus lateralis, MH- medial hamstrings (semimembranosus and semitendinosus), LH- lateral hamstrings (biceps femoris), MG- medial gastrocnemius, and LG- lateral gastrocnemius, TA- tibilais anterior, PL- peroneal longus). A footswitch indicated gait phase. Single (walking) and dual task (walking and semantic judgment) muscle activation was measured in level (0 deg) and downhill (-15 deg) walking.

Results: For Pre-A, there was no significant difference in Pre-A on single versus dual task, but there was significant age differences in Pre-A for three muscles: VMO, LH, and TA. In the VMO, there was a significant slope by group interaction with more muscle Pre-A on a level slope in younger adults. In both LH and TA the younger had more activation than the older adults. Analysis on normalised mean activity during stance phase revealed an effect for task, where single task events exhibited more activity in thigh musculature (VMO, VL, MH, and an interaction with age in LH). TA also had a single task increase, but no task event differences were found in the MG, LG, or PL.

Conclusions: Because of group differences in VMO, LH, and TA muscle Pre-A, it is believed that that these muscles have an age importance in balance during walking. However, a lack of finding EMG activity altered by dividing attention demonstrates that attention distraction may be less critical to motor control during muscle Pre-A. Observed differences in stance activity indicate more importance to motor control in this phase of gait. Further analysis of timing of the distraction stimulus is warranted.

SP-47

Spatio-temporal coordination in tennis strokes: A pilot study

E. Gillet[1], D. Leroy[1], R. Thouvarecq[1], J. Stein[2] and F. Mégrot[2]

[1]GRHAL, CETAPS EA3832, ROUEN, France and [2]INSEP, LMAP, Paris, France

Introduction: An interceptive action such as the tennis stroke can be defined as an externally-directed movement, the trajectory of which is intended to coincide with that of the desired target. The receiving players have to cope with very high time pressure caused by the high serve velocities (240 km.h-1). Successful performance of the return task depends on the ability to predict when to initiate movement. The spatio-temporal structure of a tennis stroke can be divided into two phases: the backswing (preparatory movement) and the forward swing (hitting movement). The purpose of this pilot study was to investigate the spatio-temporal coordination in serve returns performed by a world class player (51e ATP World ranking).

Methods: The receiving player was positioned on a tennis court and successfully performed either backhand or forehand strokes, depending on the serve. Two top world servers with different styles executed a number of serves (23) with combinations (3) of direction trajectories and ball rotations (3). A Vicon Peak 612TM system was used to measure the amplitudes and positions of the body gravity centre (CG) and the racquet displacements of the receiver. The lateral and vertical CG displacements were estimated from those of the first sacral vertebra [1].

Results: No difference was observed between the type of serve return concerning the occurrence ($p = .89$) and maximal amplitude ($p = .16$) of the racquet displacements and the maximal ($p = .24$) and average ($p = .63$) times of the CG rise, and the beginning lateral ($p = .75$) and vertical ($p = .22$) CG displacements. The discriminate analysis performed on all measures revealed no difference associated with the type of return (λWilks = .40; = 16.09; $p = .19$; $r2 = .72$).

Conclusions: The high degree of spatio-temporal constancy in the backhand and forehand serve returns seems to reflect a high level of spatial and temporal accuracy in the movement. Whatever the stroke, the release of the racquet movement corresponded to the time of the player's maximal CG rise. The lateral CG movement coincided with the first foot-hold on the floor after the CG rise. The player is assumed to have developed motor programmes that are temporally consistent to the extent that the processing demands were reduced to merely predicting the moment of initiation. This coordination can be considered as a means of reducing the temporal uncertainty in the serve-return situation. It may have allowed the player to reduce the number of degrees of freedom to execute his stroke while keeping the time of forward swing constant [2] or while using "funnel-like" control [3]. Moreover, it may have favoured more effective anticipation of the ball trajectory characteristics and the simplification of movement timing to reduce his computational burden. This pilot study is the basis of a research programme aimed at extracting the invariant parameters of coordination independently of the performer's specific style.

SP-48

Effects of age and pathology on stance modifications in response to increased postural anxiety

M.A. Moore[1], L.E. Stefanyk[1], M.S. Jog[2], J.S. Frank[3] and A.L. Adkin[1]

[1]Faculty of Applied Health Sciences, Brock University, St. Catharines, ON, Canada, [2]Department of Clinical Neurological Sciences, London Health Sciences Centre, University of Western Ontario, London, ON, Canada and [3]Faculty of Human Kinetics, University of Windsor, Windsor, ON, Canada

Introduction: Previous research has demonstrated that increased postural anxiety can influence postural control strategies in

young and old healthy adults (Adkin et al. Gait Posture 2000; 12: 87-93, Carpenter et al. Age Ageing 2006; 35: 298-303). In these studies, postural anxiety was induced by having participants stand on an elevated surface and execute postural tasks. The results of these studies show that the central nervous system acts to limit movement of the centre of mass when maintaining upright stance. Another method of inducing postural anxiety is to provide the threat of an external disturbance to upright stance. This study investigated the effects of a potential threat to posture on standing postural control in healthy young and old adults and individuals diagnosed with Parkinson's disease.
Methods: Sixteen healthy young adults, sixteen healthy old adults, and sixteen individuals with idiopathic Parkinson's disease stood as still as possible with feet together and eyes closed for 30-s either when not expecting or when expecting a threat to posture. The postural threat was the possibility of receiving a forward push or backward pull to the upper trunk. No limitations were placed on the postural recovery strategies that could be used (e.g., participants could take a step to recover upright stance if necessary). Confidence and anxiety, and trunk sway, in pitch and roll directions, were measured.
Results: The results showed a significant threat main effect for confidence and anxiety; young adults, old adults, and individuals with Parkinson's disease reported lower confidence and higher anxiety when expecting a threat to posture. The results also showed a significant interaction between age and threat for trunk roll angle, roll velocity, pitch angle, and pitch velocity. When expecting a threat, young adults showed a significant increase (up to 33% change) in all four measures, old adults showed a significant decrease (up to 20% change) in roll angle and velocity with no change in pitch angle and velocity, and individuals with Parkinson's disease showed no change in all four measures.
Conclusions: This study showed that postural control strategies when standing under a potential threat to posture were dependent on age and pathology. Young adults demonstrated increased amplitude and velocity of trunk sway in both pitch and roll directions when threatened. This increased trunk sway in young adults may facilitate a stepping strategy for postural recovery. Old adults showed a reduction in trunk sway amplitude and velocity especially in the roll direction whereas individuals with Parkinson's disease showed no modifications in trunk sway when threatened. These changes due to age or lack of changes due to pathology may result from changes in preferred postural recovery strategy. This study supported by a grant from NSERC (ALA).

SP-49

Effect of competing attentional demands on perturbation-evoked stepping reactions and associated gaze behavior in young and older adults

J.L. Zettel[1], W.E. McIlroy[2] and B.E. Maki[1]

[1]Centre for Studies in Aging, Sunnybrook Health Sciences Centre, University of Toronto, Toronto, ON, Canada and [2]Department of Kinesiology, University of Waterloo, Toronto, ON, Canada

Introduction: Previous studies have shown that healthy young and older adults are able to use 'stored' visuospatial information to guide the foot during rapid forward stepping reactions evoked by postural perturbation. Subjects typically did not look down toward the feet or floor during the reaction, even when obstacles or step targets increased demands for accurate foot movement. An apparent switching of attention from an ongoing visuomotor (tracking) task to the task of balance recovery occurred in over 90% of trials, but was unrelated to changes in gaze direction. This attention switching was delayed in older adults. The present study examined the influence of competing demands for visual and attentional resources by comparing trials in which the concurrent visuomotor tracking task was or was not performed.
Methods: Sudden platform motion was used to evoke compensatory stepping reactions in 12 young adults (ages 20-29) and 6 older adults (ages 61-68). Perturbation timing, direction and magnitude were varied unpredictably. The analysis focused on forward stepping reactions evoked by large backward platform translations. Obstacles and/or step targets were used to increase the demands for accurate forward foot movement in some blocks of trials. In half the trials, subjects performed a visuomotor tracking task that required them to look straight ahead at a computer monitor; in the other trials, no tracking was performed. A video-based eye tracker recorded changes in gaze direction. Stepping behavior was evaluated using video, forceplate and EMG data. Repeated-measures ANOVA was used to assess effects of performing the tracking task.
Results: Subjects looked downward less often when engaged in the tracking task; however, they did step without looking down in a substantial proportion of the no-tracking trials (young 54%, older 66%). Moreover, ability to clear an obstacle or land on a target, as well as other aspects of the stepping reactions, were largely unaffected by the tracking task. There was, however, one notable exception: in older adults, the duration and amplitude of the anticipatory postural adjustment that preceded foot-lift in the obstacle trials was reduced when performing the tracking task. This resulted in increased lateral center-of-mass motion during step execution.
Conclusions: The findings indicate that 'stored' spatial information was commonly used to guide the stepping reactions, even in the absence of competing demands for visual attention. The rapid switching of attention that follows perturbation onset presumably contributed to other (non-visual) aspects of the control, allowing young adults to step with equal effectiveness in tracking and no-tracking trials. Impaired attention switching apparently compromised the anticipatory control of lateral stability during the stepping reactions in older adults, and may be an important contributor to increased risk of falling. Funding: Canadian Institutes of Health Research

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SP-50

Explicit and implicit knowledge induce adaptation in postural control

J.A. Barela[1], P.F. Polastri[2], D. Godoi[1], M. Weigelt[3] and J.J. Jeka[4]

[1]UNESP, Rio Claro, SP, Brazil, [2]UNESP, Bauru, SP, Brazil, [3]Ludwig-Maximilians-Universität München, Munich, DE, Germany and [4]University of Maryland, College Park, MD, USA

Introduction: Continuous modification of the coupling between body sway and sensory stimuli is a signature feature of flexible, stable upright stance control. Here we investigated the effect of knowledge about visual surrounding manipulation either explicitly, by simply telling participants that a room was moving, or implicitly, by changing abruptly the amplitude and velocity of the room's movement.

Methods: Twenty healthy adults participated in this study constituting two groups of ten participants. Ten participants remained in upright stance inside a "moving room" for eight trials of 60 sec apiece. The room was stationary in the first trial. In the following seven trials, the room oscillated at 0.2 Hz with a velocity of 0.6 cm/s and amplitude of 0.5 cm. Before the fifth trial, participants were informed that the room was moving (explicit knowledge condition). The other ten participants went through the same procedures but in the fifth trial the room moved at a higher velocity and amplitude (3.5 cm/s and 3.2 cm, respectively) (implicit knowledge condition).

Results: The results showed that all participants responded to the 0.2 Hz visual stimulus in both conditions. In the explicit knowledge condition, body sway responses decreased in the trials after the participants were told that the room was moving, indicating decreased coupling (downweighting) of the visual stimulus No change was observed in total amount of body sway or its phase relationship with room movement. In the implicit knowledge condition, body sway responses dramatically decreased to the visual stimulus when the velocity and amplitude of the room increased, indicating decreased coupling (downweighting) of the visual stimulus. Moreover, in the trials after the velocity and amplitude changes, body sway responses to the visual stimulus did not return to the level prior to the visual stimulus change.

Conclusions: These results suggest that adaptive behavior occurs when knowledge about the stimulus is provided both explicitly and implicitly. Adaptive behavior due to implicit knowledge may be crucial for controlling posture due to the continuously changing surrounding environment.

SP-51

HEAD-TRUNK COORDINATIONS DURING VARIOUS LOCOMOTOR TASKS ON THE TREADMILL

S. Viel, M. Vaugoyeau and C. Assaiante

CNRS-Marseille, Marseille, France

Introduction: In adults, bipedal locomotion is an automatic rhythmic activity, without any postural difficulty. Nevertheless, in specific locomotor activities involving balance difficulty or attentional process, the subjects have to regulate propulsion as well as body orientation and segmental stability. The aim of this experiment was to study locomotor and postural adaptations performed by adults during backward walking and amble walking that disturb natural inter-limb coordination.

Methods: Ten healthy young men, without low back pain history or trunk deformity performed several locomotor tasks on a treadmill. For each condition: backward and forward amble walking the speed was imposed by the treadmill (5,4 km/h). An automatic optical TV image processor (SMART Emotion) was used to analyse the kinematics of head, shoulders, trunk, and pelvis. Orientation and stabilization of these segments in roll, pitch and yaw were studied as well as the locomotor parameters (stride length and cadence).

Results: The main results emerging from this study are first, that the locomotor parameters are affected when the natural interlimb coordination is modified in both locomotor tasks. In backward locomotion the stride length decreased whereas the cadence increased. By contrast, in forward amble locomotion the stride length increased whereas the cadence decreased. Second, the main postural adaptation in backward locomotion was an "en bloc" operation of the head-trunk unit instead of an articulated operation adopted in normal forward walking. Moreover minor postural adaptations occurred in amble locomotion.

Conclusions: These results suggest that during backward locomotion, increasing balance difficulty, postural adaptations occur whereas during amble locomotion that increases attentional process no significant modifications of the postural reference frame occur. This study is supported by la direction générale des armées (Ministère de la défense N° 0334045)

SP-52

The concurrent cognitive task of backward counting and gait velocity are reduced during blind navigation in four directions

N. Paquet[1], F. Sabagh-Yazdi[1], Y. Lajoie[2] and C. Rainville[3]

[1]School of Rehabilitation Sciences, University of Ottawa, Ottawa, ON, Canada, [2]School of Human Kinetics, University of Ottawa, Ottawa, ON, Canada and [3]Montreal University Institute of Geriatrics, Montreal, QC, Canada

Introduction: Spatial navigation is known to require the integration of sensory, motor and cognitive functions (Trullier et al. 1997). However, few studies investigated the cognitive processes that underlie blind navigation. In postural control, the performance of a concurrent cognitive task decreased as the difficulty of a postural task increased (Lajoie et al. 1993). Our aims were to determine the effect of backward counting on distance and direction errors and gait velocity during blind navigation, and to determine the effect of blind navigation on the production of backward counting responses.

Methods: Seventeen healthy subjects (28 ± 7 y/o) executed two single tasks and one dual task. The first single task was to navigate without vision towards previously seen targets located on the floor 8 meters ahead, behind, to their right or to their left. Vision was occluded by opaque goggles. Subjects walked until they believed their feet were on the target. They walked forward towards the target ahead, backwards towards the target behind, and sideways without crossing the legs towards the right and left targets. The second single task was to count backwards in increments of 3 while sitting. The dual task was to perform the two single tasks concurrently, i.e. blind navigation while counting backwards. The final feet positions were marked on the floor. Distance traveled (DT), angular deviation (AD) to a straight trajectory, body rotation (BR) relative to space and gait velocity were measured. The number of correct responses produced during the backward counting was recorded. The effect of dual task on dependent variables was determined with one-way ANOVAs.

Results: The three measures of navigation precision, i.e. DT, AD and BR, were not significantly different during the dual task as compared with the single task. However, during the dual task, subjects produced significantly less correct backward counting responses per second during forward (0.55 ± 0.16), backward (0.55 ± 0.15) and rightward navigation (0.52 ± 0.17) than during sitting (0.63 ± 0.19, $p<0.05$). Gait velocity was significantly slower ($p<0.01$) during the dual task than the single navigation task in all directions.

Conclusions: Our results indicate that navigation precision was not affected by the concurrent cognitive task. This might be due to the instructions given to subjects as to give priority to reaching targets over producing backward counting responses during the dual task. In contrast, the cognitive task was affected by the concurrent blind navigation task. This is in agreement with previous studies done during walking (Beauchet et al. 2005) and perturbed standing (Ansersson et al. 2002). It suggests that blind navigation towards a remembered target requires a high level of attention, which leaves insufficient cognitive resource to optimally perform an additional, concurrent cognitive task. Our finding that gait velocity is slowed during the dual task further support that the attentional demand of blind navigation is high.

Vestibular Functions

SP-53

OPTIC FLOW AND THE CONTROL OF HEADING DIRECTION IN PERSONS WITH VESTIBULAR DISORDERS

M. Hanna[1], P. Stapley[2], A. Feldman[3] and A. Lamontagne[1]

[1]School of P & OT, McGill University, Montreal, QC, Canada, [2]Department of Kinesiology, McGill University, Montreal, QC, Canada and [3]Department of Physiology, University of Montreal, Montreal, QC, Canada

Introduction: Vestibular disorders lead to balance and mobility problems which, in turn, have an impact on autonomy and may lead to falls. In the presence of a vestibular disorder, walking is characterized by a difficulty in controlling heading direction especially when eye or head rotations are involved. Such rotations induce a change in optic flow (OF) direction, projected at the observer's eye. OF is related to visual perception of self-motion and used in the specification of walking direction and speed. In patients with vestibular disorders, the control of locomotion might be impaired due to changes in visual-vestibular interaction.We hypothesized that unlike healthy subjects, patients with vestibular disorders, will make errors in the heading direction in response to changes in the OF in virtual environment.

Methods: 5 subjects with a unilateral vestibular lesion (UVL), 2 subjects with a bilateral vestibular lesion (BVL), and 5 healthy controls, who were ambulatory, were recruited from the Vestibular Rehabilitation Clinic at the Jewish Rehabilitation Hospital.Subjects were instructed to walk straight in the virtual room (Caren-2 by Motek), which was projected in a head-mounted display (HMD). During the evaluation, the focus of expansion of the large virtual room was randomly located either towards the lesion (+40°, +20°), away from the lesion (-20°, -40°) or straight ahead (0°), as the subject walked along a 5 meter walkway. During the experiment, a 10-camera Vicon system was used to record head, thorax, pelvis, foot orientation and to calculate the body center of mass trajectory.

Results: Healthy individuals modified their heading direction in the physical world in the direction opposite to the focus of expansion (FOE), resulting in small deviation errors within the virtual world. Subjects with a vestibular disorder showed different patterns of modulation of heading direction in response to shifts in the FOE location, but no significant difference in deviation was observed compared to healthy controls. Subjects with a UVL tended to turn their head more towards the lesion, while subjects with a BVL, had a tendency to keep their head motionless in the real world, when adapting their heading direction.

Conclusions: The altered steering behaviors in response to changing FOE locations in the subjects with a vestibular disorder suggest that the vestibular system may interact with visual perception and/or integration of optic flow direction information while walking. Results may contribute to the understanding of how persons with vestibular dysfunctions utilize visuospatial perception to control locomotion. Funded by CIHR.

SP-54

The regulation of vestibular afferent information during full, partial and no vision while standing

D. Jessop, A. Desjardins and B. McFadyen

Center for Interdisciplinary Research in Rehabilitation and Social Integration (CIRRIS), Department of Rehabilitation, Faculty of Medicine, Laval University, Quebec, QC, Canada

Introduction: The visual and the vestibular systems are considered to play major roles in postural control, but the interaction between them is still not well understood. Different studies using galvanic vestibular stimulation (GVS) have shown that the size of the response such stimulation is increased when the availability of other sensory information, in particular vision, is limited. In the present preliminary study, we investigated the effect of monocular versus binocular vision on vestibular regulation of postural stability while standing in a healthy, young adult population.

Methods: To date, the postural stability of 4 young adults (mean age of 24.92 years, +/- 5.97 years; mean height of 1.81 m.) has been measured during eight different conditions. The conditions involved a combination of eyes open, eyes closed, right-eye open and left-eye open during GVS with the anode electrode on the right and left sides. The subjects were asked to fix their gaze on a 2cm-diameter target situated 2.5 m in front of them, at eye level. Using a Grass S88 stimulator connected to an isolation unit, GVS was provided via a small, tonic, transmastoidal current (about 1 mA). Three non-collinear IRED markers were also placed on each foot, the trunk and the head. An Optotrak system (model 3020) was used to track these markers and force platforms (AMTI) were also used to evaluate ground reaction forces under each foot. Dependent variables analysed included the angular movement (roll) and the linear displacement of the head and trunk in the frontal plane, and the vertical ground reaction forces (all compared to pre-stimulation initial values). Although the results for only 4 subjects were available at this point, differences between conditions were compared using a repeated measures ANOVA.

Results: For GVS with the anode electrode on the left side, the changes in vertical forces, head and trunk roll and subsequent

head and trunk lateral displacements support a trend towards a greater effect of monocular than binocular vision on vestibular regulation. With the anode electrode on the right side, the data was more variable across subjects but similar results were seen. DISCUSSION: Our data to date suggest that monocular visual information in a healthy population doesn't correspond to the same postural response to galvanic vestibular stimulation as compared to full vision. The addition of more subjects and with closer analyses of other variables such as centre of pressure is warranted. Overall, there appears to be some upregulation of vestibular information during asymmetrical vision.
Conclusions: This work will help to better understand vestibular regulation of postural adaptation and its interaction with the visual system. These data will also provide the base on which to initiate future investigations of postural control in populations with both symmetric and asymmetric visual deficits.

SP-55

The interactions between visual, vestibular and haptic terrain information while using a white cane during gait in normal, young adults

A. Desjardins, D. Jessop and B.J. McFadyen

Center for Interdisciplinary Research in Rehabilitation and Social Integration (CIRRIS), Department of Rehabilitation, Faculty of Medecine, Laval University, Quebec, QC, Canada

Introduction: Although the effects of vestibular control on locomotion have been studied more and more of late, they are still not well understood. Following recent studies using galvanic vestibular stimulation, we now know that regulation by the vestibular system can be dependent on gait phase (Bent et al., 2005) and context (e.g., running versus walking; Jahn et al, 2000). In this preliminary study, we investigated the effects of the context of sweeping a walking aide (a white cane used by persons with visual impairments) on vestibular regulation with and without vision in healthy, young adults.
Methods: To date, the walking patterns of 4 young adults (mean age of 31 years, +/- 12.6 years; mean height of 1.81 m.) were measured during the combination of different conditions including, walking with eyes open and closed, with and without a white cane and with and without galvanic vestibular stimulation (GVS) with the anode electrode on the right and left sides. The white cane used was 1.38 metres long with a rolling nylon tip. Subjects were instructed to sweep the cane side-to-side across their travel path in front of them at their self-selected frequency. GVS was provided by a tonic, transmastoidal current (about 1 mA) using a Grass S88 stimulator connected to an isolation unit. Three non-collinear IRED markers were placed on each foot, the trunk and the head. These markers were tracked with an Optotrak system (model 3020) and dependent variables included gait speed, step length and width, angular movement of the head and trunk in the frontal and sagittal planes, and lateral movement of the trunk centre of mass. Differences were compared between conditions using a repeated measures ANOVA.
Results: The preliminary results showed that upper body roll was only affected by GVS. Lateral foot placements showed significant vision and GVS effects, the latter beginning 2 steps following GVS. Although a vision by cane interaction approached significance a few steps after gait initiation, and one subject did show less effect of GVS with eyes closed while using the cane, overall, there were no significant effects observed for cane use to date.
Conclusions: At this point in our analyses it appears that vestibular regulation was not greatly changed by the haptic terrain information supplied by the presence and sweeping motion of the cane in the right hand. More subjects will be added to confirm this preliminary observation. It is possible, however, that the addition of visual deficits, extensive training for cane use, or walking in more uncertain environments might increase the focus on the haptic terrain information from this walking aide and affect vestibular regulation.

SP-56

Cervical muscle afferents dominates vestibular afferents in neck vibration and causes short latency EMG activation of lower leg

M. Magnusson[1], G. Andersson[2], S. Gomez[3], M. Karlberg[1], R. Johansson[1] and P. Fransson[1]

[1]Institute of Clinical Sciences,Lund, Dept of Otorhinolaryngology, Lund, Sweden, [2]Dept of Neurophysiology, Ins of clinical sciences, Lund, Lund, Sweden and [3]Faculty of Applied Sciences,, University of the West of England,, Bristol BS16 1QY, UK, UK

Introduction: The importance of cervical proprioceptive afferents in human postural control is a matter of controversy. To study the matter a directed stimulation to the cervical muscles with evaluation of postural and muscular reactions would be would be elucidative. Local vibration may invoke such responses and was used inn the present study. However, vibration may activate vestibular receptors as well. We therefore also aimed to determine the effect of vibration on postural responses in a second set-up where it could be assumed that the contribution of proprioceptive and vestibular afferents would differ, aiming to determine if the cervical vibration would induce its effects mainly over vestibular or proprioceptive afferents.
Methods: During bilateral perturbation with vibration we investigated EMG from the triceps surae and the tibialis anterior together with force plate data in 10 healthy normal subjects, when perturbed by bilateral posterior neck muscle vibration. Care was taken not to make contact with bone In a second experiment, vibratory stimuli were applied bilaterally and separately to the splenius muscles of the neck and high on the planum mastoideum to keep vibrators at level with the labyrinth and takeing care not to make contact with the muscle insertion on the tip of the mastoid.
Results: The tibialis anterior was activated at latencies of 70-100 ms while the triceps surae was inhibited at the same latencies. At offset the opposite pattern was observed. Activation was followed by postural deviation. In a second experiment, vibratory stimuli were applied bilaterally and separately to the splenius muscles of the neck and high on the planum mastoideum. The cervical vibration induced reproducible EMG and postural responses in the anteroposterior direction, particularly on cessation of vibration. EMG and postural responses were considerably lower and less consistent with mastoid vibration. Previous reports suggest that vibratory stimulation could propagate

to the vestibular organs and generate a vestibular-induced postural activation.
Conclusions: Previous reports suggest that vibratory stimulation could propagate to the vestibular organs and generate a vestibular-induced postural activation. Our findings indicate rather that cervical muscles afferents play a dominant role over vestibular afferents when vibration is directed towards the neck muscles. Together these findings implicate an important role for the cervical afferents in postural during upright stance in healthy humans.

SP-57

Vestibular drop attacks in Meniere's disease: from a viewpoint of vestibular evoked myogenic potentials

T. Murofushi[1], S. Iwasaki[2] and H. Ozeki[3]

[1]Otolaryngology, Tokyo Postal Services Agency Hospital, Tokyo, Japan, [2]Otolaryngology, University of Tokyo, Tokyo, Japan and [3]Otolaryngology, Toshiba General Hospital, Tokyo, Japan

Introduction: In 1936, Tumarkin first described sudden drop attacks, which occur in patients with Meniere's disease. They suddenly feel sensation of being pushed to the ground, then fall without loss of consciousness. This phenomenon has been known as Tumarkin's otlithic crisis or vestibular drop attack (VDA). It has been assumed that VDA occurred with sudden changes in endolymphatic fluid pressure with inappropriate otolith stimulation causing reflex-like vestibulospinal loss of postural tone. Recently it has been shown that vestibular evoked myogenic potentials (VEMP) became available for evaluating function of the otolithic organs, especially saccule. Thus, we supposed that VEMP testing might be useful to evaluate the otolithic function in case of VDA. Herein, we present three cases with VDA secondary to Meniere's disease with a special reference to VEMP.
Methods: Patients At our clinic 116 patients (36 men and 80 women, 23- 91years of age) were diagnosed as having definite Meniere's disease. The diagnostic criteria for Meniere's disease had been determined according to the AAO-HNS criteria (1995). In our study, we used the following criteria for inclusion as definite VDA. 1) Patients should have a history of sensation of being pushed to the ground and should have real events of falling without loss of consciousness. 2) Patients should show no associated neurological symptoms at the time of falling. Of the 116 Meniere's disease patients, three patients met this inclusion criteria for VDA. Methods Clinical records of the 3 patients with VDA were reviewed. They had undergone VEMP testing. VEMPs were recorded using surface electrodes. Electromyographic (EMG) activity was recorded in the supine from symmetrical sites over the upper half of each SCM with a reference electrode on the lateral end of the upper sternum. During the recording, the patients were instructed to hold up their heads in order to activate the SCM. The EMG signals on the stimulated side were amplified and bandpass-filtered (20-2000 Hz). Rarefaction clicks (0.1 ms, 95 dBnHL [normal hearing level]) were presented through a headphone. The stimulation rate was 5 Hz, and the analysis time was 50 ms. Responses to 100 stimuli were averaged twice.
Results: All of the 3 patients (1 male and 2 female) had bilateral Meniere's disease. The age of the onset of VDA ranged 64 to 66 years. On VEMP testing, all of them showed normal responses at leaast in one side. Two of the 3 patients had VEMP testing before and after oral administration of glycerol (1.3g/kg body weight). Effects of glycerol on VEMPs were positive in these patients. In other words, they showed significant improvement of VEMP amplitudes after glycerol administration.
Conclusions: In the present study, it was supposed that VDA could occur under the conditions that the endolymphatic hydrops exist in the otolithic organ and the otolithic functions are in the reversible stage.

SP-58

What can we detect through foot pressure analysis in patients with vertigo?

K. Ishikawa, M. Yin, W. Wong, Y. Shibata and Y. Itasaka

Department of Sensory Medicine, Division of Otorhinolaryngology, Head & Neck Surgery, Akita University School of Medicine, Akita, Akita Profecture, Japan

Introduction: Vestibular lesion should cause gait instability. Its character might reflect site and severity of the lesion. But how those abnormalities are to be delineated objectively? We have conducted gait analysis by the use of foot pressure sensor placed on both feet in patients with various types of vestibular lesion. Whole data were reviewed and summarized to evaluate its usefulness and limitations.
Methods: Foot pressure sensor (F-scan system) has been employed for the present study. Regarding the methods using this gait analysis system has already been reported previous meetings. In a brief, those following variables were used for the analysis of gait: coefficient of variations of gait phase related parameters such as stance, swing, and double support; integrated foot pressure; stability, movement and average length of trajectories of center of force (COF); pattern of foot pressure progression during stance which was divided three phase: body weight acceptance, body weight translation, and body weight thrust. Patients were those with vestibular neuronitis (14 cases), acoustic neuroma (61 cases) and spino-cerebellar degeneration (12 cases). Healthy adults (23 cases) served as a control.
Results: Gait instability is depicted by increment of coefficient of variation of each gait phase. The severer gait instability becomes, the greater those CV values become as has been reported so far. Visual cue plays an important role providing feed forward information for steady locomotion. Unilateral vestibular lesion could shift body center of gravity toward the lesion side, which leads greater foot pressure on the lesion side foot with greater horizontal sway of COF during gait, especially under gait with eyes closed. Irregular pattern of foot pressure progression could also reflect gait instability, and the greatest was found in SCD. As for the average length of COF, significantly longer trajectories were found especially when compared to vestibular neuronitis.
Conclusions: Thus gait analysis by the use of foot pressure sensor could provide useful information for the understanding of

gait abnormality caused by vestibular system lesion. It is desirable to perform the gait test for evaluation of gait abnormality with dizzy patient.

Assistive Technologies and Devices

SP-59

Frontal plane adaptation to gait initiation related to rollator use

J. Tung[1], W.H. Gage[2], K.F. Zabjek[5], B.E. Maki[3] and W.E. McIlroy[4]

[1]Rehabilitation Science, University of Toronto, Toronto, ON, Canada, [2]Kinesiology, York University, Toronto, ON, Canada, [3]Kinesiology, Waterloo University, Waterloo, ON, Canada, [4]Centre for Studies in Aging, Sunnybrook Health Sciences Centre, Toronto, ON, Canada, [5]Physical Therapy, University of Toronto, Toronto, ON, Canada and [6]Toronto Rehabilitation Institute, Toronto, ON, Canada

Introduction: Gait initiation (GI) involves a volitional lift of the foot, potentially creating medial-lateral (ML) instability. To counter this, an anticipatory postural adjustment (APA) is produced to propel the body towards the stance leg, indicated by an ML excursion of the center-of-pressure (COP) towards the swing leg prior to foot-off (FO). The rollator (4-wheeled walker) is an assistive mobility device shown to improve efficiency and reduce joint loading during walking, and provides significant frontal plane stability under standing conditions. The aim of this study is to investigate its role in frontal plane stability for a dynamic task. We hypothesized that an ML APA is generated through the hands/rollator, indicated by a decreased peak COP excursion under the feet compared to baseline (without rollator), coupled with a concomitant COP displacement generated through the rollator prior to foot-off.
Methods: 12 adults (21-34y) without motor impairment performed a GI task under two conditions: A) freestanding and B) with a rollator. Subjects began by standing still, and initiated gait with the same foot upon verbal cue. Each condition was repeated 10 times. Separate forceplates were used to collect ground reaction forces beneath the feet and the rollator for 7 sec.
Results: Representative trials from an individual subject are shown in Figure 1. Initial results analyzed from 6 subjects show peak ML COP excursion under the feet is reduced by 43% (SD = 17%) when using a rollator. A concomitant COP displacement through the rollator was observed prior to foot-off. After foot-off, COP through the rollator continued to rise.
Conclusions: Initial results, showing diminished COP excursion through the feet and a modest COP rise through the rollator, support the hypothesis that the rollator is used to generate an APA. The finding that COP continues to rise following foot-off suggests that the rollator may also be used in a reactive manner for frontal plane stability. Post-hoc analysis will assess the possibility of stiffness as a mechanism for control.

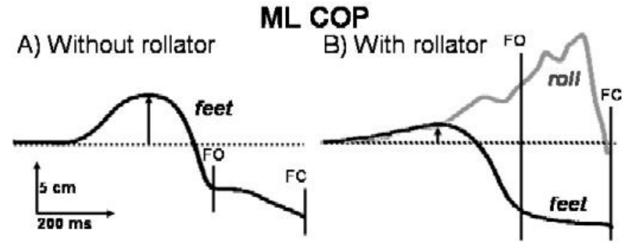


Fig. 1. ML COP under feet (black trace) without rollator (A), and with rollator (B). APA amplitude, indicated by peak COP (arrows), is visibly diminished with the rollator. The peak COP measured under the rollator (gray trace) occurs after foot-off (FO). Broken line represents midline, with +ve values towards stepping foot.

SP-60

Development and testing of a new robotic gait and balance training system for individuals post-stroke

E. Lewis[1], J. Santos[1], J. Patton[2], A. Makhlin[1], G. Crombie[2], M. Peshkin[1], K. Settle[2], E. Colgate[1] and D.A. Brown[1]

[1]Chicago PT, LLC, Evanston, IL, USA and [2]SMPP, Rehabilitation Institute of Chicago, Chicago, IL, USA

Introduction: One major limitation in today's clinical setting is the need for clinicians to support the weight of patients with poor balance and prepare to respond to loss of balance while, at the same time, trying to deliver effective movement cues and manual guidance. Based upon expressed needs from clinician focus groups, we developed a robotic device that allows clinicians to work with patients on gait and balance exercises while focusing entirely on guiding, cuing, and challenging the patient rather than on holding and/or catching the patient during the exercise session. This robotic system was designed to minimize disturbance forces on a patient that would impede their motion.
Methods: The robotic gait and balance system, the Kineassist, is composed of three major components: 1) a three degree of freedom hip/pelvis mechanism, 2) an independent torso controller to provide trunk control and alignment, and 3) a buggy that moves overground along with the patient in any direction he/she chooses. To test whether the device was able to minimize disturbance forces on a patient during functional motion, we measured sacral trajectories, via an 8-camera reflector-based motion analysis system (Eagle Digital), in overground gait and balance tasks from non-impaired subjects (n=5) and persons with hemiplegia (n=10. The subjects performed four tasks at a comfortable speed three times each, both inside and outside of the Kineassist: sit to stand, stand to sit, whole body reaching, and forward walking. Nonimpaired subjects were also asked to perform each of the tasks first as quickly as they could then and at a pace that was half their normal pace to measure device performance at different speeds. Sacral marker speed and range of motion values were compared in and out of the Kineassist.
Results: Trajectories of motion with and without the Kineassist were similar. However, when comparing speed of the sacral marker in both nonimpaired subjects and subjects with hemiplegia across all of the different tasks, on average, there was a significant reduction in speed for tasks performed in the Kineassist ($p<0.05$). Also, the sacral marker range of motion was significantly reduced for many of the tasks performed in the Kineassist ($p<0.05$).

Conclusions: The Kineassist is a device that allows clinicians and patients to safely perform gait and balance exercises while allowing the clinician to focus on training cues rather than fall protection. The system minimizes disturbance forces and allows patients to move relatively unimpeded during functional tasks and only interferes when loss of balance occurs. However, trajectories are slower and reduced in range with the Kineassist compared without the same tasks performed outside of the Kineassist. The Kineassist is a useful device for studying balance and gait in persons at risk for balance and may be a useful tool for clinicians who are seeking to challenge gait and balance for patients in more realistic environments. Funded by a grant from NIH NICHD/NCMRR #R42HD51240.

SP-61

FES-based training and gait evaluation of hemiplegic patients using a microsensor on their valid leg

R. Héliot[1], B. Espiau[1], C. Azevedo Coste[2], D. David[3] and D.B. Popovic[4]

[1]INRIA RA, INRIA, Saint Ismier, France, [2]DEMAR, INRIA/LIRMM, Montpellier, France, [3]CEA-LETI, CEA, Grenoble, France, [4]SMI, Aalborg Univ., Aalborg, Denmark and [5]Fac. Electrical Engineering, University of Belgrade, Belgrade, Serbia, Yugoslavia

Introduction: Functional Electrical Stimulation (FES) allows the generation of artificial movements in patients with motor disability. FES has been shown to be a valuable method for training stroke patients in early stage of hemiplegia in order to improve the recovery of walking skills. In this framework, an accurate sequencing of muscle stimulation sequences is essential, Existing FES systems usually provide with fixed stimulation patterns tuned and programmed off-line. The triggering of stimulation sequences is often achieved manually by the clinician assisting the patient. If the patient walks faster or slower than the programmed sequence, the movements of the healthy and the paretic leg might not be well coordinated.

Methods: We designed a method that monitors on-line the ongoing movement and generates the stimulation sequences to be applied onto the muscles. Our approach relies on a unique wireless micro-sensor (embedding 3 accelerometers + 3 magnetometers) placed on the valid leg, a model of the sensor measurements being computed during walking. Since the motion is cyclical, we use a non-linear oscillator model, which can autonomously generate a cyclical output. We fit the model parameters with measurements by optimization, and build an observer of the model, which "filters" the sensor measurements. Since the observer is an oscillator itself, it is possible to reconstruct the oscillator phase, and generate the related control.

Results: For each muscle, stimulation parameters (amplitude, pulse width, frequency) are derived according to the computed phase and a pre-programmed stimulation pattern. This can be done online for patient re-education. Another important issue addressed is the performance evaluation of the patient's gait. During a given training protocol for stroke patients, it is of great interest to assess improvement of the gait. Such evaluation can be achieved through standard tests (Barthel Index, Ashworth scale, ...) performed by clinicians, or by measuring some gait variables: locomotion speed, symmetry, which however require specific equipment to be measured. Our aim is to provide with a gait analysis system which could easily give an objective criteria of gait quality. By placing an accelerometer on the healthy shank, we can measure some helpful variables, as stride frequency. We perform a spectral analysis of the accelerometer signal, and exhibit a frequency ratio that shows good correlation with gait speed and symmetry.

Conclusions: The system only requires a small and easy-to-use sensor, thus not disturbing the patients' gait. We developed a convenient analysis software that gives a quantitative result right after the test. We thus believe that such a tool could be of great help in rehabilitation centres.

SP-62

Evaluation of a lower limb exoskeleton for gait enhancement

A. Forner-Cordero[1], J.C. Moreno[1], A. Cullell[1], E. Navarro[2], P. Isabel[2] and J.L. Pons[1]

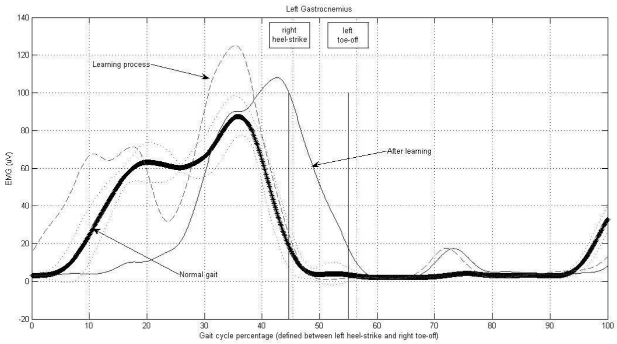
[1]Biomedical Engineering, Instituto de Automatica Industrial (IAI-CSIC), Arganda del Rey (Madrid), Madrid, Spain and [2]Biomechanics, Facultad de la Actividad Fisica y el Deporte (INEF, UPM), Madrid, Madrid, Spain

Introduction: The design and evaluation of exoskeletons to enhance human performance during gait is an emerging field of research. These exoskeletons can be seen as gait orthoses and they must account for the user's intention in order to apply the forces adequately. It is questioned if an exoskeleton designed to support patients suffering muscle weakness can enhance performance in healthy subjects. This exoskeleton was designed considering the requisites of the leg depending on the gait phase. The knee flexes during swing and extends for foot contact to support the body weight. This function was simulated by switching two springs of different stiffness, and a knee-ankle-foot-orthosis was built to compensate for leg muscle weakness. Here, the learning process in the use of this orthosis by healthy subjects is analysed.

Methods: The use of this exoskeleton was investigated experimentally. An orthosis incorporating pairs of linear springs at the knee and ankle joints was fitted to each participant. The transition between each spring (support and swing) was determined by ankle dorsiflexion at toe-off. There were 4 experimental gait conditions: 1) normal, 2) orthosis without actuation, 3) actuated orthosis without learning and 4) after learning (60 min walking and practicing). The lower limb motion, EMG data and ground reaction forces were measured. The EMG electrodes were placed bilaterally at the Gastrocnemius, Tibialis Anterior, Biceps and Rectus Femoris following the SENIAM recommendations. The EMG data was rectified and filtered to obtain the EMG gait patterns in each condition.

Results: The data indicated that subjects need to "learn" to use the orthosis. The step duration increased during the learning process. During the learning process the EMG activities were less stereotyped and the averaging of these trials resulted in large standard deviations. The bursts were also larger than normal and

had longer durations. This was reversed after the practice (see figure 1).
Conclusions: At the end of the learning process, the EMG pattern showed lower and shorter bursts of EMG activity. This suggests that the exoskeleton could improve aspects of gait endurance and fatigue beyond its original application to patients suffering quadriceps weakness



EMG gait patterns of the left gastrocnemius: normal (thick), with orthosis before (dashed) and after (solid) learning.

SP-63

Realism and Gait Characteritics of Walking in a Virtual Reality Mobility Simulator

J.E. Deutsch[1], J. Lewis[1], A. Minsky[1], G. Burdea[2] and R. Boian[3]

[1]Rivers Lab, UMDNJ, Newark, NJ, USA, [2]CAIP Center, Rutgers, Piscataway, NJ, USA and [3]Mathematics and Computer Science, Babes-Bolyai University, Cluj-Napoca, Romania

Introduction: Virtual environments (VE) are designed to simulate the real world. Presence in the VE is achieved when the user is immersed and experiences a sense of realism. We have designed a walking simulator in which the user experiences hardware driven haptic (surface) effects linked to visual stimuli in a VE. The purpose of this study was to measure subjects' perception of realism and the temporal and spatial characteristics of gait while walking in a VE mobility simulation where visual and haptic effects were manipulated.
Methods: The mobility simulator consisted of 2 Rutgers Mega-Ankle (RMA) robot platforms, each with 6 pneumatic cylinders, 6 linear potentiometers and 1 force sensor, allowing the system to change and measure positions and forces. A haptic control interface operated the RMAs and was connected to a PC. Haptic conditions (ice or mud) were rendered by the platforms, and audio and visual stimuli of a street crossing were presented as they walked. Eleven healthy subjects (20-50 years) participated. Over-ground temporal spatial gait parameters were measured using self-selected walking speed (n=3) on a GaitRite mat. Subjects stood on the platforms facing the display screen and were instrumented with markers, one on each fifth metatarsal, lateral malleolus, lateral knee, hip, and trunk. Subjects were unweighed (40% bodyweight) by a Biodex frame. They walked on the mobility simulator until they achieved a criterion gait pattern. Walking trials (n=22) of street crossing simulation were performed. Visual (on or off) and haptic (support surface of level ground, ice, or mud) stimuli conditions were randomly presented. Subjects rated realism, visual, and surface experiences using a visual analogue scale (VAS). Force data at initial swing (IS), and initial contact (IC) were extracted from the RMA platforms. Temporal spatial parameters of gait were collected with and extracted from the 6-camera Peak System.
Results: See Table 1.
Conclusions: Modest immersion was reported. Realism ratings were greatest during concurrent haptics and visual stimuli presentations. Reports of realism were more strongly influenced by the visual scene than haptic effects. Velocity decreased with the addition of haptics. Forces increased at appropriate gait events, IS to overcome mud and IC to restrain mud and ice effects. Kinematics and step length were unaffected by visual and haptic manipulations.
Mean VAS Scores, Velocity, and Forces by Condition

	Street Crossing	Visual Ice	Haptics Ice	Visual + Haptics Ice	Visual Mud	Haptics Mud	Visual + Haptics Mud
Realism (VAS)	4.1	4.0	2.8	3.9	4.4	2.7	4.7
Feel (VAS)	Not Tested	2.6	1.5	3.0	3.7	3.0	3.9
See (VAS)	Not Tested	9.5	0.2	9.8	9.6	0.7	9.5
Velocity (m/s)	0.217	0.205	0.183	0.191	0.201	0.193	0.192
Forward Force (N) @ IS	33.91	40.95	34.95	34.90	36.94	49.11	49.56
Upward Force (N) @ IS	17.42	16.50	17.67	17.71	17.38	41.20	40.20
Downward Force (N) @ IC	65.64	68.94	62.79	74.36	68.21	66.81	74.23

Monday, July 16, 2007

Special posters associated with Dr. Aftab Patla from these sessions are grouped together for presentation in the Burlington room.

*Visual Functions**

MP-1

In known contexts walking is not controlled by vision

A. Hallemans[2] and P. Aerts[1]

[1]Biology, University of Antwerp, Antwerp, Belgium and [2]Health Care, University College of Antwerp, Antwerp, Belgium

Introduction: During static balance tasks adults rely heavily upon visual feedback information for postural control. The role of vision in dynamic balance tasks is less obvious. This study investigates the impact of visual deprivation on the gait pattern in order to gain more insight into the role of vision in the control of walking.
Methods: In healthy adults (n=20, age 28±7) gait was compared between 3 different conditions: normal vision (1), deprivation of the lower half of the visual field (2) and no vision (3). We used a set-up consisting of 6 automated cameras (Vicon® Mcam 60, 120Hz.) and 2 force platforms (AMTI 0,4 x 0,5m, 1080Hz.) to record walking at self-selected speed. Step–time parameters, joint kinematics and kinetics were calculated using the Vicon Plug-in-Gait® model. Differences between the 3 conditions were investigated using a Chi square test for repeated measurements. Significance was set at $p<0.05$.
Results: Results are shown in table 1. Only gait characteristics that show significant differences between the 3 conditions are shown.
Conclusions: Very little differences are observed between the conditions 1 and 2. The most obvious difference between the conditions 1 and 3 is the large decrease in self-selected walking speed. Since speed largely determines all other gait characteristics, most likely many of the differences in gait can be attributed to the difference in self-selected walking speed. These observations would suggests that in known contexts, gait is largely an automated process and visual feedback information plays little role in controlling the movement patterns.

Table 1

		Normal Vision			Restricted Visual Field			No Vision			Chi	p
	Percentiles	Q1	Q2	Q3	Q1	Q2	Q3	Q1	Q2	Q3	n=2	
Speed	dimensionless	0.39	0.42	0.45	0.37	0.39*	0.46	0.21	0.31*	0.37	26.39	.000
Step frequency	dimensionless	0.57	0.62	0.64	0.58	0.62	0.68	0.50	0.56*	0.61	13.65	.001
Stride length	x leg length	1.40	1.49	1.57	1.34	1.43*	1.56	0.89	1.19*	1.43	30.03	.000
Step Width	x pelvic width	0.52	0.66	0.78	0.59	0.65	0.79	0.60	0.79*	0.93	12.93	.002
ROM pelvic obliquity	°	7.0	10.1	12.5	5.9	10.1	11.1	4.7	6.3*	8.6	19.44	.000
ROM pelvic rotation	°	6.2	9.2	12.2	6.6	7.6	10.2	5.0	5.8*	8.7	13.00	.002
ROM hip flex/ext	°	42.4	46.2	47.8	40.6	44.3	45.5	33.0	38.2	44.1	14.78	.001
ROM hip abd/add	°	11.8	14.6	15.2	10.2	12.6	15.0	8.2	10.2*	13.5	14.78	.001
Ankle PF at LR	°	3.2	3.8	5.2	1.6	4.7	6.3	0.9	3.8(*)	4.7	5.68	.056
Ankle DF	°	11.8	14.4	15.6	12.3	15.3	17.8	14.4	16.2*	17.8	13.00	.002
Ankle PF at TO	°	25.5	27.4	30.7	24.7	26.1	29.3	17.6	22.9*	25.5	15.44	.000
Hip flex moment	Nm/kg	-1.1	-0.9	-0.7	-1.0	-0.8	-0.7	-1.0	-0.8*	-0.5	7.63	.022
Ankle PF moment	Nm/kg	1.4	1.5	1.6	1.4	1.5	1.6	0.8	1.3*	1.4	9.88	.007
Knee power abs	Watt/kg	-1.1	-0.5	-0.4	-0.7	-0.4*	-0.3	-0.4	-0.2*	-0.1	17.38	.000
Ankle power abs	Watt/kg	-0.6	-0.3	-0.2	-0.5	-0.2	-0.1	-0.4	-0.2	-0.1	6.39	.039
Ankle power gen	Watt/kg	2.4	3.2	3.9	2.5	3.3	3.8	1.0	1.8*	2.5	16.13	.000

Results from the Chi square test. Significant differences with normal vision are indicated by an *.

MP-2

Visual acuity during treadmill walking

B.T. Peters[1], R. Van Emmerik[2], R. Brady[1] and J.J. Bloomberg[3]

[1]Neuroscience Laboratory, Wyle Laboratories, Inc., Houston, TX, USA, [2]Kinesiology, University of Massachusetts, Amherst, MA, USA and [3]Neuoscience Laboratory, NASA-Johnson Space Center, Houston, TX, USA

Introduction: An awareness of the physical world is essential for successful navigation through the environment. Vision is the means by which this awareness is made possible for most people. However, without adequate compensation, the movements of the body during walking could impair vision. Previous research has shown how the eyes, head and trunk movements are coordinated to provide the compensation necessary for clear vision, but the overall effectiveness of these coordinated movements is unknown. The goal of the research presented here was to provide a direct measure of visual performance during locomotion, while also investigating the degree to which coordinated head and body movements can be altered to facilitate the goal of seeing clearly.
Methods: To measure visual acuity, subjects identified the orientation of the "gap" in sequentially-presented Landolt Ring optotypes. The size of the optotypes varied according to the subject's success rate until the threshold was determined. Walking acuity was compared to a standing measure obtained in the same way. Far (4.0 m) and near (0.5 m) walking acuity was compared in Study 1. In a second study, the near condition was repeated at five walking velocities ranging from 1.0 up to the 1.8 m/s used in Study 1. In a third study, the optotype presentation was constrained to occur either at or between heel strikes during far target viewing. A measure of distance between the subject and a theoretical point in space where the visual fixation of the point would require a minimal amount of eye movement was calculated using motion analysis data. This head fixation distance (HFD) was used to quantify the collective effects of changes in the non-ocular body movements on the visual fixation goal.
Results: Visual acuity was not affected by walking during the far target condition in Study 1. However, despite a change in HFD that is consistent with a reorganization of body movements that

reduce the magnitude of the required eye movements, a measurable decrement in acuity was observed for the near condition. Acuity improved systematically as the walking velocity was reduced during Study 2, but decrement in acuity was present during near viewing even at the slowest walking speed. Results from Study 1 showed that walking acuity is equivalent to standing acuity for far viewing distances. However, Study 3 showed that acuity is not consistent across the step cycle with a measurable decrement observed at heel strike when compared to the between heel strike presentations.

Conclusions: Facilitated by coordinated movements of the head and body, visual acuity of far objects is maintained while walking. However, these mechanisms, in conjunction with the associated eye movements, are not able to fully compensate for near target fixation and heel strike perturbations. The direct measure of walking acuity demonstrated may be a useful for diagnosing abnormal gaze stabilization mechanisms and quantifying their functional consequences.

MP-3

Landing when stepping down to a new level: insights on the sensory control used when 'online' vision is blurred or occluded

J.G. Buckley[1], M.J. MacLellan[2] and S.J. Bennett[3]

[1]Vision & Mobility Laboratory, Optometry, University of Bradford, Bradford, West Yorkshire, UK, [2]Gait and Posture Laboratory, Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada and [3]Research Institute for Sport & Exercise Sciences, Liverpool John Moores University, Liverpool, Merseyside, UK

Introduction: When stepping down from one level to another, the landing limb has to arrest downward CM momentum and subsequently receive and safely support bodyweight before level walking can begin. Such step downs are performed over a wide range of heights and predicting when the instant of contact with the lower level will be made is likely a critical factor. Landing unexpectedly could mean the limb is not appropriately prepared to attenuate the body's downward momentum and/or not optimally positioned to receive and safely support bodyweight. As with other forms of locomotion, stepping down is regulated through both feed-forward and feedback mechanisms. Predicting the time and place of contact is determined visually prior to initiating the stepping movement and then regulated online using visual and proprioceptive feedback. The present study explored the contribution from online visual feedback by investigating how landing when stepping down was affected by blurring or occluding vision immediately prior to movement initiation.

Methods: Ten healthy participants (32.3 ±7.9 yr) stepped, from a standing position, down from 3 levels (7.3, 14.6, & 21.8cm) onto an adjacent forceplatform, either coming immediately to rest or proceeding directly to walking across the laboratory. Repeated trials were undertaken under habitual vision conditions or with vision blurred or occluded 1 to 2 seconds prior to movement initiation. Landing mechanics for the initial contact period were characterized using landing limb knee and ankle angle, vertical loading and stiffness, and support limb un-weighting. Landing stability was assessed by determining a/p and m/l stability margins ($SM_{a/p}$, $SM_{m/l}$) and a/p and m/l CM velocity, at the instant of landing.

Results: Movement time and ankle plantarflexion were significantly greater when vision was blurred or occluded, whereas knee flexion, vertical loading and stiffness and support limb un-weighting were significantly reduced. $SM_{a/p}$ and $SM_{m/l}$ at landing increased significantly when vision was blurred or occluded, whereas a/p and m/l CM velocity decreased. Adaptations under occluded conditions tended to be greater than those observed for blurred conditions but these differences were only significant in 1 or 2 cases. Most variables were significantly affected by stepping task and step height.

Conclusions: Findings indicate that under blurred or occluded vision conditions subjects 'sat back' on their support limb and used their lead limb to probe for the ground. Hence, they did not fully commit to weight transfer until somatosensory feedback confirmed they had safely made contact. These findings confirm the role of 'online' visual feedback in determining the time and place of contact when stepping down. In the absence of online visual feedback, stepping dynamics are modulated in advance of contact to utilize/optimise proprioceptive feedback to ensure landing occurs safely.

MP-4

The influence of optic flow on gait initiation

K. Ustinova[1], L. Knaut[2], P. Laberge[4], A. Lamontagne[3] and A. Feldman[4]

[1]Department of Physical Therapy, Central Michigan University, Mount Pleasant, MI, USA, [2]School of Rehabilitation, University of Montreal, Montreal, QC, Canada, [3]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [4]Department of Physiology, University of Montreal, Montreal, QC, Canada

Introduction: While walking, we perceive the environment as motionless despite the shift in the visual image on the retina. In order to perceive the environmental constancy, an appropriate internal transformation of optic flow is needed. To be efficient, such sensory transformation should be initiated somewhat before the gait onset. This hypothesis implies that, by artificially changing the optic flow from a stationary to a moving pattern, one can influence the latency of gait initiation. We tested this suggestion by analyzing the latency of gait initiated in response to expansion or compression of a virtual hallway at different rates. For comparison, we also analyzed the latency of gait initiated in a physical environment at different speeds in response to a sound signal

Methods: Virtual optical stimulation was delivered to healthy subjects (n=10) via a head-mounted display. The virtual expansion or compression of the hallway resembled to the natural changes in the optic flow occurring during walking forward or backward, respectively, in a physical hallway. In each of the two types of stimulation, 9 rates ranged from 0.5 to 8 m/s were used in randomly selected trials. Standing subjects were instructed to initiate walking forward (2 steps) as soon as they detected a change in the optic flow. In another set of trials, subjects started walking in real space in response to a sound tone. They were instructed to initiate gait at a preferred speed or at a faster or

slower self-chosen speed. The latency, duration, length, maximal and average velocity of the first step were analyzed.
Results: The rate of change in optic flow strongly influenced the latency of gait initiation and kinematic characteristics of the first step. In all subjects, the latency of the first step systematically decreased whereas the length, maximum and averaged velocity of the first step increased with the increasing rate of expansion or compression of the virtual hallway. In contrast, the latency of sound-initiated gait remained the same regardless of walking speed.
Conclusions: Results show that by unexpectedly changing optical flow, one can influence the latency of gait and its speed, thus confirming the hypothesis that walking is associated with an active internal transformation of optic flow in order to perceive the environment as motionless. The same mechanism might be functional in sound-initiated gait but in this case, the transformation of optic flow is chosen beforehand, according to the desired speed so that gait at different speeds could start at the same latency. Results can be used in rehabilitation, in particular, to facilitate gait initiation in Parkinson's patients.

MP-5

Comparison of stair descent performance of healthy elderly users and non-users of eyeglasses: a preliminary study

S. Nadeau[1], G. Giraudet[3], J. Gresset[4], A. Brière[2] and D. Gravel[1]

[1]École de réadaptation, Université de Montréal, Montréal, QC, Canada, [2]Centre de recherche interdisciplinaire en réadaptation (CRIR), Institut de réadaptation de Montréal, Montreal, QC, Canada, [3]R&D Vision, Essilor INTL, Saint-Maur, France and [4]École d'optométrie, Université de Montréal, Montréal, QC, Canada

Introduction: At the transition from level walking to stair descent, visual information is important for successful and safe negotiation of stairs. Thus, loss of visual capabilities and the optical distortions created by lenses may alter the ability to negotiate stairs, particularly at rapid speed. The purpose of this study was to characterize the stair descent performance of healthy elderly persons, both users and non-users of spectacles, and to compare two types of multifocal lenses (bifocal vs. progressive lenses).
Methods: Twenty healthy adults over 60 were assessed during stair descent. Ten did not need spectacles for stair negotiation (controls; Ctrl) whereas others were regular users of bifocal (n=5; Bfcl) or progressive (n=5: Prog) lenses. Examination of their vision confirmed that the subjects' refractive errors in both the Bfcl and the Prog groups were appropriately compensated by their current spectacles. Stair descent was assessed at natural and fast speed on a four-step staircase having instrumented steps and handrails. Time-distance parameters and three-dimensional kinematics data were obtained using foot switches and an Optotrak system, respectively. Non-parametric statistical analyses were used to assess differences in cadence and foot kinematics between groups for three stair gait cycles.
Results: No participants used the handrails to manage the stairs. Stair descent time-distance (cadence) variables were not different except for a trend (P= 0.095) for the first step between the Bfcl group and the two others (133.5 steps/min ± 0.06 vs. 146.9 ±16.9 and 147.6 ±17.6 for the Bfcl, Prog and Ctrl, respectively) at fast speed. Regarding the heel and toe positions relative to the stairs, no differences were observed except for a 2-cm trend towards a more anterior foot position on the third step for the Bfcl group (P= 0.095) at fast speed. When the foot reached the level of the intermediate (or obstacle) step during the first stair gait cycle, the linear velocity and acceleration of the foot were slightly higher for the Prog group than the Bfcl group (e.g. mean horizontal linear acceleration: 7.45 m/s-2 vs. 4.18 m/s-2). However, none of the comparisons reached the level of significance (P<0.05) and no differences in these parameters were found between the Ctrl group and the healthy subjects wearing spectacles.
Conclusions: To reduce cadence might be the first adaptation used by elderly persons who wear bifocal lenses to ensure safe transition from level walking to stair descent at rapid speed. This might allow them to better cope with the optical distortion created by the distance- and near-vision segments of their spectacles without having to change the kinematics of foot clearance. Future research will need to confirm this finding in a larger group of subjects.

MP-6

Can Tai Chi Improve Spatial Orientation in Subjects with Visual Impairments?

S. Fu[1], W.W. Tsang[1], L. Fung[2] and E. Tsai[2]

[1]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China and [2]Department of Physical Education, Hong Kong Baptist University, Hong Kong, China

Introduction: People with visual impairments utilize their remaining senses to learn about their environment, and their cognitive ability to determine what the sensory information "mean" for spatial orientation. In this connection, Tai Chi has shown to improve joint proprioception, and cognitive abilities. A question therefore arises as whether spatial orientation can be improved by Tai Chi training for people with visual impairments.
Methods: This was a prospective single-blinded controlled trial. Twenty-eight subjects with visual impairments were recruited to join a 4-month Tai Chi (n=14, 9 partial and 5 complete blind)) or music appreciation (n=14, 11 partial and 3 complete blind) program. Subjects in the Tai Chi group received training in the Yeung style for 1.5 hours, 2 times per week for 4 months. The music appreciation participants attended similar number of sessions. All participants underwent pre- and post evaluation on spatial orientation within 2 week prior to and after the programme. The spatial orientation task required the subjects to walk from point-to-point along a 'trained" and 3 'novel" paths. The walking paths were captured by a motion analysis system (Vicon, UK) using passive reflective markers placing onto both shoulders. The errors in orientation along the "trained" and "novel" paths were calculated.
Results: The errors in orientation was significantly less during "trained' than "novel" paths (p<0.05). Subjects with partial blindness made greater errors during the "trained" path than subjects with complete blindness (p< 0.05). After intervention, Tai Chi participants with partial blindness showed significantly less errors in orientation along the "trained" (Fig. 1, p < 0.05), but not the "novel" paths (Fig. 1, p>0.05). Insignificant changes along both 'trained" and "novel" paths were observed in the Tai Chi

participants with complete blindness, and subjects in the music group (all $p>0.05$, Fig. 1).

Conclusions: Tai Chi can improve spatial orientation in subjects with partial visual impairments. After a 4-month Tai Chi programme, the error in spatial orientation along a "trained" path was significantly reduced in subjects with partial visual impairments. Such improvement may relate to improvement in joint proprioception and/or cognitive ability.

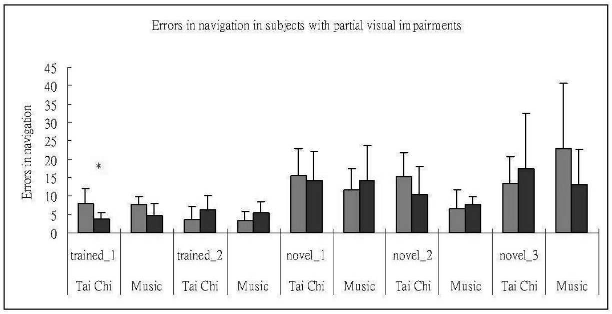


Figure 1. * denote significant difference at $P<0.05$ unpaired t-test

MP-7

The limits of step trajectory modification

R.F. Reynolds and B.L. Day

Sobell department of Motor Neuroscience and Movement disorders, Institute of Neurology, UCL, London, UK

Introduction: The body is thrown at the beginning of a step and subsequently falls under gravity until caught by the landing foot[1,2].However, if desired foot placement alters mid-step,limb trajectory can be rapidly adjusted[3].But there are limitations on its magnitude, which we investigate here.

Methods: Subjects stepped to a target that jumped laterally(7-21cm) at different times.Normal stepping was compared to foot reaching with the body supported.Foot placement accuracy and body COM were measured.

Results: Subjects found medial target jumps more difficult than lateral jumps ($p<0.05$;fig1).This difference was less apparent when reaching.There was an inverse relation between jump distance and target accuracy(fig 1a).Similarly,subjects were less able to alter foot trajectory when the timing of the jump occurred later(fig 1b).There was a significant correlation between swing duration and target accuracy during steps ($p=0.45$; $p<0.001$).This relationship was weaker for the reach condition($p=0.19$;$p=0.158$).The ability to prolong the step was greater for lateral than medial target jumps(fig 1a&b).Furthermore COM trajectory could be adjusted during the swing phase in response to lateral,but not medial target jumps.

Conclusions: Swing phase can be prolonged allowing the body to fall further laterally. Also during the swing phase extra lateral force is generated to push the body COM further. These mechanisms cannot be used to the same extent to move the body medially.This explains why foot placement cannot be altered mid-step to the same extent when the target jumps medially.That any medial shift of foot placement occurs at all despite no detectable changes in COM, means there is some scope for altering foot placement altering COM trajectory, whilst still catching the falling body.

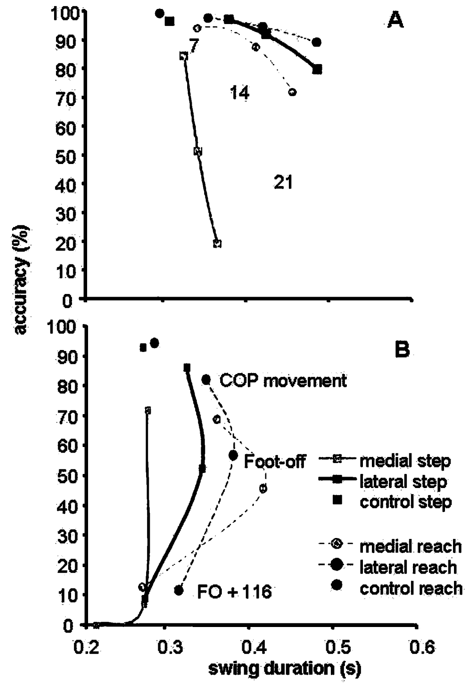


Figure 1. Relation between foot placement accuracy and swing duration during target jumps.

(A) shows the effect of increasing target jump distance.
(B) shows the effect of altered jump timing.

MP-8

Crossing an obstacle that is in the lower peripheral field leads to adaptations of muscle activation in the landing phase

V. Weerdesteyn[1], D.S. Marigold[3] and J. Duysens[1]

[1]*Rehabilitation Medicine, Radboud University Medical Centre, Nijmegen, Netherlands,* [2]*Research, Development & Education, Sint Maartenskliniek, Nijmegen, Netherlands and* [3]*Gait and Posture Lab, Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada*

Introduction: Adequate avoidance of obstacles during walking heavily relies on visual information. However, the quality of visual information required in different situations is not well understood. In a previous study on time-critical obstacle avoidance on a treadmill, subjects performed equally well under central and peripheral vision with only 18% of peripheral vision trials showing downward saccades (Marigold et al., 2006). If a saccade occurred, however, it was always directed towards the landing area behind the obstacle. This observation indicates that a specific phase of the obstacle crossing stride, i.e. the landing phase, may benefit from central as opposed to peripheral vision. It was hypothesized that changes in the execution of landing between trials with or without obstacle fixation could be revealed using a detailed EMG analysis of upper and lower leg muscles.

Methods: Eight young females participated in this experiment. There were two visual conditions: a central vision condition where participants fixated an obstacle attached to a bridge on the treadmill and a peripheral vision condition where participants fixated an object two steps ahead. Obstacles were released randomly in one of three phases during the step cycle, namely late stance, early swing or mid swing. For both vision conditions, ten trials of each of the obstacle release conditions were collected. EMGs were recorded from the biceps femoris (BF), rectus femoris (RF), tibilais anterior (TA), and the medial head of the gastrocnemius (GM). Gaze fixation was monitored using a video-based eye tracking device.

Results: In the control strides without the obstacle there were no differences in EMG activity during landing between the vision conditions. For obstacle crossing strides, normalized EMG activity was calculated from 100 ms before to 100 ms after foot contact behind the obstacle for the central and peripheral vision conditions, excluding trials with saccades. The results showed that in the peripheral vision condition there was considerably more RF activity before landing as compared to the central condition. A similar tendency could be observed in the GM. TA showed less activity in the peripheral vision condition just after foot contact.

Conclusions: The higher amplitudes of RF and GM before landing reflect larger anticipatory activity for preparation of weight acceptance after landing. This may be because peripheral vision does not provide the same quality of visual information as central vision does to predict the instant of foot landing. The reduced TA (and increased GM) activity could reflect participants aiming for a foot-flat landing, in order to increase stability at the instant of landing. In conclusion, even though central vision is not required for good performance in terms of failures, the subtle changes as observed in the EMG patterns in the peripheral vision trials can be interpreted to underlie compensatory mechanisms for reduced visual information.

MP-68

Stepping adaptations when negotiating a raised surface: a comparison between multifocal and single vision spectacles in the elderly

L. Johnson[1], J.G. Buckley[1], C. Harley[1] and D.B. Elliott[1]

[1]Division of Optometry, School of Life Sciences, University of Bradford, Bradford, UK and [2]Division of Rehabilitation Studies, School of Health Studies, University fo Bradford, Bradford, UK

Introduction: Adequate toe clearance is a critical factor in successful negotiation of a raised surface. Inaccurate visual assessment of the exact location and dimensions of a raised edge, or of the foot position in space may lead to inadequate foot clearance with a subsequent stumble, trip or fall. Epidemiological evidence indicates that elderly multifocal-wearers are at increased risk of falling, especially on curbs or stairs and this is likely due to optical effects including refractive blur when viewing beyond approximately 40 cm through the near-vision correction portion of a multifocal lens, prismatic jump (bifocal) and distortion (varifocal) that are inherent in multifocal designs, all of which could result in inaccurate judgement of distances. Yet little is known regarding stepping strategies used by elderly multifocal-wearers during transitions between levels. The purpose of this study was to determine the effects of wearing multifocal compared to single distance vision spectacles upon stepping characteristics and toe clearance parameters when negotiating a raised surface.

Methods: Nineteen healthy older adults (72.7 ± 4.2 yrs) repeatedly approached and stepped up and along a raised platform (14.9 cm high, 3 m long, 1 m wide) the height of which was randomly increased by 1.0 cm or decreased by 0.6 cm every fourth trial, whilst wearing bifocal, varifocal or single distance vision spectacles. Toe clearance parameters and step characteristics from lead limb heel contact before the platform until lead limb foot contact on the platform were assessed using a 6-camera, Vicon motion analysis system.

Results: When wearing multifocal compared to single distance vision spectacles the trail limb was placed further from the platform ($p=.05$). Consequently the lead foot crossed the raised edge later in the swing phase and the foot landed closer to the step edge when wearing bi- or varifocals ($p = .003$). Vertical toe clearance also increased ($p<.001$) which may have been due to the changes in trail foot placement and/or the increased ankle dorsiflexion found in the multifocal conditions ($p=.01$). Forward centre-of-mass velocity at foot contact during the penultimate and crossing steps was reduced when wearing multifocal compared to single vision spectacles ($p=.01$), and there was an increased incidence of 'inadvertent' heel (but not toe)-step contacts ($p=.03$).

Conclusions: Toe clearance and foot placement strategies when negotiating a raised surface are adapted when wearing bi- and varifocal compared to single distance vision spectacles which suggests that the optical effects inherent in their design result in unreliable visual information regarding the exact location and dimensions of the raised edge. Although the adaptations utilised ensured vertical toe clearance increased, the increase in heel contacts (which unlike a toe contact would likely not result in a trip) suggest subjects may have adopted this strategy to increase propreoceptive feedback.

MP-69

Stepping to recover balance in complex environments: is online visual control necessary or sufficient?

C.Y. Scovil[1], J.L. Zettel[2], E.C. King[1] and B.E. Maki[1]

[1]Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada and [2]Centre for Vision Research, York University, Toronto, ON, Canada

Introduction: Visuospatial information (VSI) regarding environmental constraints is essential when stepping in response to balance perturbation. Recent results suggest that VSI that is acquired and stored prior to perturbation onset (PO) is normally used to guide these rapid step reactions; however, the extent to which online (post-PO) VSI can be used has not yet been fully explored. To examine this, we manipulated access to VSI during step reactions in an unpredictable environment. We hypothesized that subjects would be unable to avoid challenging, unpredictable obstacles and would use less appropriate stepping patterns, if forced to rely on online VSI alone.

Methods: Subjects stood on a motion platform, behind a barrier (1.4m wide, 60cm high, 10cm from toes) that contained a

narrow slot (20cm wide, bottom of slot 25cm above floor) through which the foot could be moved forward. The slot location (left or right of midline) was varied randomly, and subjects were prevented from seeing the slot location prior to the start of the trial. Step reactions were then evoked by a large platform translation after a random 2-7s delay. 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). Subjects performed 20 backward-translation (forward-step) trials for each condition, plus 24 unpredictable forward- and lateral-translation trials. Stepping behavior and obstacle avoidance were evaluated from kinematic and forceplate data. Repeated-measures ANOVA was used to compare visual conditions.
Results: To date, seven subjects have been tested (age 23-30): five were able to step through the slot during balance recovery (79% success rate); two were unable, regardless of visual condition. Within the five subjects, there were no differences in success rate between conditions (p=0.26); however, in the online-VSI condition, subjects were more likely to take a small initial step prior to stepping through the slot (62% online-VSI, vs. 41% stored-VSI, 44% normal-VSI; p=0.02). In addition, subjects were more likely to step through the slot with the foot contralateral to the slot location in the online-VSI condition (35% online-VSI, vs. 9% stored-VSI, 9% normal-VSI; p=0.004). Stepping also appeared to be delayed in the online-VSI trials, but this has yet to be fully analyzed.
Conclusions: The similarity between stored-VSI and normal-VSI responses suggests that control of step reactions normally does depend on stored VSI, and that online VSI is not necessary for guiding the foot past obstacles. Using online-VSI, subjects were less able to reliably select the most appropriate foot for stepping, and step modifications appeared to be directed at increasing time for visuospatial scanning and processing. This suggests that online VSI does not allow for optimal step planning and may be sufficient only if the step reactions can be delayed. FUNDING: Canadian Institutes of Health Research

MP-70

Does peripheral vision contribute to online control of grasping reactions evoked by an unexpected perturbation when walking in an unfamiliar environment?

E.C. King, T.A. Lee and B.E. Maki

Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada

Introduction: Rapid reach-to-grasp reactions can play a critical role in balance recovery following a postural perturbation. Control of these reactions is highly dependant on a determination of environmental features, specifically potential handhold locations. Observations from our ongoing studies have indicated that subjects typically reach and grasp a handrail without foveating directly on the hand or grasp location at any point during the reaction, even when the perturbation is unexpected and the environment is unfamiliar. Although it is possible that the hand trajectory is guided by visuospatial information acquired and stored prior to perturbation onset (PO), it is also possible that peripheral vision plays an important role in on-line control of the reaction. This study is the first in a planned series of experiments aimed at determining the role of peripheral vision in controlling rapid balance reactions. In this study, we address a hypothesis that peripheral vision does contribute to the online control of reach-to-grasp balance reactions.
Methods: Grasping reactions were evoked in healthy young adults (age 20-30) using an extended (2x6m) motion platform configured to simulate an office environment, including a stair, handrail and various visual distracters. The subject was given the task of making a phone call, which required opening a door and walking to the far end of the platform. The platform was triggered to move suddenly as the subject approached the handrail. A deception approach was used to ensure that the first perturbation was truly unexpected. Two additional trials were then performed. Each subject was tested in one of two visual conditions: 1) no peripheral vision (noPV), in which goggles occluded all but the central 15-20° of vision for each eye, and 2) full vision (FV), in which the goggles were not worn.
Results: Five of ten FV and four of ten noPV subjects have been tested to date. Within the FV subjects, three grasped the handrail successfully in the first trial, and two reached toward the rail but did not attempt to grasp it. In contrast, during the first trial, only one of the four noPV subjects reached for the rail and none attempted to grasp it. Interestingly, the noPV subjects were more likely to try to grasp the rail in the later trials, once they were aware that it was present, yet they overshot the rail in two of three grasp attempts. In contrast, the FV subjects successfully grasped the rail in four of five attempts, despite never having looked directly at the rail during the reaction. Results from the full cohort will be presented at the meeting.
Conclusions: The ability of FV subjects to successfully grasp the rail without looking at it, and the reduced ability of noPV subjects to do the same, suggest that peripheral vision may aid in online control during the prehension phase of the grasping reaction. However, further analysis, involving the full cohort, is needed to confirm this preliminary conclusion. Funding: Canadian Institutes of Health Research

MP-71

Changes in balance and gait following cataract surgery

J.L. Helbostad, M. Oedegaard, K. Taraldsen, R. Moe-Nilssen and O. Sletvold

Dept of Neuroscience, NTNU, Trondheim, Norway

Introduction: Most falls in older persons occur during walking. Impaired balance, gait and vision are important risk factors for falls. There is some evidence that cataract surgery reduces fall risk. Few studies have assessed whether improvements in vision improves balance and gait. The aim of the study was to assess changes in standing balance and gait following cataract surgery.
Methods: 80 persons of 70 years or more (mean=79.5, SD=5.0) undergoing cataract surgery at one or both eyes participated. Vision, balance and gait were assessed before surgery and 6 weeks after surgery. Postural sway during standing was assessed with eyes open and closed on flat floor and on foam. Walking under three different speed conditions was assessed when walking in full lighting (>250 lux) and subdued lighting (5-10 lux). Gait

was assessed by gait speed, trunk movements and gait cycle parameters.
Results: 30 % reported to have fallen the year before study onset. Preliminary results demonstrated significant changes in visual acuity, stereopsis, field vision and contrast vision ($p < 0.017$). Standing postural sway with eyes open ($p<0.001$) but not eyes closed ($p>0.22$) decreased. Gait characteristics like lateral trunk movements ($p = 0.037$) and stride-to-stride variability in trunk movements ($p=0.022$), stride-to-stride variability in single support ($p=0.02$), when walking in subdued lighting changed following cataract surgery. Gait speed did not change ($p>0.07$). Preoperative visual acuity and field vision explained the changes in gait parameters ($p<0.019$).
Conclusions: These results based on 80 of a total of 180 participants, have demonstrated improvements in balance and gait characteristics 6 week following the cataract surgery. The reduced sway during standing with eyes open may be understood as better ability to use vision as an anchor for balance control. The changes in gait were seen for the most challenging condition, the low light condition.

MP-72*

The importance of binocular vision to the control of dynamic stability during adapted locomotion

M.J. MacLellan[1], J.G. Buckley[2] and A.E. Patla[1]

[1]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada and [2]Department of Optometry, University of Bradford, Bradford, UK

Introduction: Although under monocular viewing conditions the central nervous system (CNS) is able to use cues in the environment to estimate depth, it has been reported that binocular vision is important in determining accurate exteroceptive information. For example, when one eye is occluded limb elevation during obstacle clearance is increased (Patla et al, 2002). Although such adaptations increase margins of safety during adaptive locomotion, it is currently unknown if determinants of dynamic stability are also affected. The purpose of this study was to determine if binocular vision is important to the control of dynamic stability when stepping onto a stationary or moving target.
Methods: From a standing position, seven participants walked along a pathway outfitted with 6 targets to direct foot placement. The initial target was placed on a platform that could move in a medial or lateral direction at 0.05 m/s. Trials were repeated under 3 visual conditions (binocular vision, contralateral eye occluded, and ipsalateral eye occluded) and 5 moving platform conditions (no movement, lateral or medial movement at heel-off (HO), and lateral or medial movement 200 ms post HO). Dynamic stability was determined at instance of ground contact as the distance from the COM to the leading heel in the A/P (COM-$BOS_{A/P}$) and M/L (COM-$BOS_{M/L}$) directions. Values for perturbed conditions were compared to those obtained in trials under binocular viewing when the platform was stationary. Monocular trials were grouped due to no differences between contralateral and ipsalateral conditions. A vision (binocular, monocular) by movement direction (medial, lateral) by movement initiation (HO, 200 ms post HO) 3-way ANOVA was used to determine statistical differences.
Results: Time to toe-off was longer during monocular compared to binocular vision conditions ($F(1,6) = 6.61$, $p < 0.015$) and swing time when stepping to the initial target was significantly shorter in trials when platform movement occurred at heel-off ($F(1,6) = 5.15$, $p < 0.026$). COM-$BOS_{A/P}$ was greater in medial compared to lateral perturbations ($F(1,6) = 13.55$, $p < 0.001$) and COM-$BOS_{M/L}$ was decreased in HO compared to 200 ms post HO in lateral perturbations but this trend was reversed in medial perturbations (direction by time interaction, $F(1,6) = 55.74$, $p < 0.001$). $COM_{A/P}$ ($F(1,6) = 7.82$, $p < 0.006$) and $COM_{M/L}$ ($F(1,6) = 55.74$, $p < 0.001$) velocity were reduced under monocular compared to binocular conditions.
Conclusions: Findings suggest that under monocular conditions the CNS adopted a cautious strategy to increase dynamic stability, even though other adaptations were used in an attempt to place the foot on the target as accurately as possible. These results indicate that binocular vision is important to the control of certain aspects of dynamic stability. Findings also highlight that the CNS has the flexibility to increase dynamic stability whilst also making adaptations to achieve foot placement accuracy.

MP-73*

Visual information from the lower visual field is important for walking on different ground terrain

D.S. Marigold and A.E. Patla

Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: The central nervous system receives a multitude of visual information as an individual traverses through an environment. Several studies have illustrated the importance of using visual information in an on-line manner to facilitate walking (Patla, Ecological Psychology, 1998, 10: 287-302; Patla and Greig, Neuroscience Letters, 2006, 397: 110-114). While individuals fixate approximately two steps ahead when walking in a challenging environment (Marigold and Patla, Neuroscience, in press), the question remains as to whether individuals attend to visual information from the lower visual field (and therefore sections of the ground terrain preceding the point of fixation). Indeed, peripheral visual information from the lower visual field is used for stepping over obstacles (Marigold et al., Experimental Brain Research, in press; Patla, Ecological Psychology, 1998, 10: 287-302). Thus, the purpose of this study was to determine whether visual information from the lower visual field is utilized when negotiating different ground terrain.
Methods: Ten healthy young adults (mean age of 26.1 yrs) and ten healthy older adults (mean age of 74.1 yrs) walked across a walkway where the middle section consisted of varying ground terrain (i.e. solid, compliant, slippery, irregular, uneven, and rocky) forming a 5x3 grid of 15 blocks of surfaces. Participants also walked across a solid, uniform walkway (i.e. control trials). In half of the walking trials participants wore special glasses that blocked the lower visual field. Position markers placed on the head recorded the mean and maximum head pitch angle across the multi-surface terrain.
Results: Mean (vision main effect: $P < 0.0001$) and maximum (vision main effect: $P = 0.0002$) head pitch angle (i.e. downward head movement) were increased when the lower visual field

was blocked compared to walking with normal vision. Specifically, the mean and maximum head pitch angles were increased by approximately 7 and 9 degrees, respectively, when the lower visual field was blocked. Two different strategies for dealing with the blocked lower visual field were observed: some participants demonstrated a single large increase in head pitch angle (reflected by the maximum head pitch measure) whereas others demonstrated a shift in the mean head pitch angle (reflected by the mean head pitch measure). These strategies were independent of age.
Conclusions: The results suggest that visual information from the lower visual field is important for safely negotiating varying ground terrain. In addition, the results have implications for those who wear multi-focal glasses where distant (i.e. from ground level) visual information from the lower visual field is blurred.

MP-74*

Where we look as we approach and pass through a narrow aperture in a variety of form of locomotion?

T. Higuchi[1], M.E. Cinelli[2] and A.E. Patla[3]

[1]Health Promotion Science, Tokyo Metropolitan University, Tokyo, Japan, [2]Cognitive and Linguistic Sciences, Brown University, Providence, RI, USA and [3]Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: Spatio-temporal patterns of gaze fixation were analyzed as eight normal participants approached and passed through a narrow aperture created by two doors in one of four forms of locomotion: normal walking, walking while holding a 63-cm horizontal bar with or without rotating the shoulders to cross an aperture, and wheelchair use.
Methods: All participants were naïve to use a wheelchair. Relative aperture widths were 1.02, 1.10, and 1.20 times their minimum passable width under each form of locomotion. Gaze fixations were analyzed during two phases: the approach phase (i.e. from the start of the trial to the time when a decrease in velocity was initiated) and the reaching phase (i.e. from the time when a decrease in velocity was initiated to the time of crossing the doors). Fixation locations were classified into one of four categories: aperture, doors, path, or other and the durations of each fixation were quantified. We also analyzed gaze fixation locations and durations at the time of crossing the doors.
Results: Two factors affected the location where the participants fixated: the size of an aperture, and whether the form of locomotion is walking or wheelchair. Narrow door apertures resulted in more fixations directed towards the doors regardless of the form of locomotion. Gaze patterns were quite similar in the three walking conditions: the participants fixated towards the door aperture and the doors evenly (about 40% each) during the approach phase; however, more fixations were directed towards the door aperture (about 50 %) than at the doors (about 40%) during the reaching phase. Prior to crossing the doors, the participants fixated toward the door aperture for 700-800 ms durations on 80% of trials. In contrast to the walking condition, the wheelchair condition showed that the participants fixated more frequently at the doors (65%) than toward the door aperture (20%) during both the approach and reaching phases. At the time of crossing the doors in the wheelchair conditions, fixations were at the doors in 70% of trials.
Conclusions: The effect of form of locomotion on gaze fixation patterns may suggest the differences in the role of gaze behavior for successful passage through an aperture between walking and wheelchair use. When walking, visual information obtained with a fixation at a center of aperture (e.g., an optic flow), is likely to be sufficient to afford a successful passage even if an individual hold a long bar, while the information about the location of the door with respect to the hands placed on wheelchair-handrims is required during a wheelchair use to avoid collisions

MP-75*

Gaze fixation patterns during navigation around tall obstacles

R. den Otter[1] and A.E. Patla[2]

[1]Human Movement Sciences, University of Groningen, Groningen, Netherlands and [2]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: Goal directed locomotion requires sampling of relevant visual information in order to reach the desired goal. Previous research on gaze behavior during path selection has focused on environments with low obstacles (i.e. traffic pylons) where information about the spatial layout of the obstacle grid is readily available. However, when obstacles are tall (> 2 m) walkers do not have direct access to this information, and the travel goal may be obscured by obstacles. Under these circumstances, action choices have to be based on visual information that becomes available during walking. The main objective of this study was to find out what visual information is important for path selection in environments that are crowded with tall obstacles.
Methods: 6 healthy young subjects (23- 33 yrs) were instructed to traverse a 12 by 8 grid in which 12 tall (2.33 m) posts were placed. Six grids were generated, each with 3 entrance and 2 exit points, so that the total number of trails for each subject was 30. Subjects were allowed to select their own prefered route through the grid and to walk at a self selected speed. Gaze fixations (stationary position of gaze for > 100 msec) were classified with respect to 4 possible fixation locations: 'Posts', 'Travel path', 'Goal', and 'Elsewhere'.
Results: The average time that was spent before gait initiation was short (870 ms) and during this phase no active scanning of the environment took place. Fixation patterns during the travel phase were not random but were directed at features relevant for path selection and steering. Goal fixations were most frequent (45%), followed by travel path fixations (25%) and post fixations (21%). Fixations on locations 'Elsewhere' accounted for only 9% of the total fixation time. Spatial gaze fixation patterns varied as a function of traveling phase, with goal fixations becoming more prominent when walkers approached the goal. The majority of the post fixations were on posts in distant rows of the grid.
Conclusions: As indicated by the short time spent before gait initiation, most of the information that was used for path planning was not preplanned but obtained online. The results further suggest that gaze during the travel phase was directed at features of the environment that are relevant for this task.

Furthermore, fixation patterns varied according to the sort of information that was important within each particular travel phase, with less time spent on post fixations and increasingly more time spent on goal fixations when approaching the goal. The relatively large proportion of fixations on the goal suggests that the information obtained during gaze fixation not only serves to identify features relevant for path selection but may also play a role in heading control.

MP-76*

Task dependent gaze fixation patterns during navigation in an environment with tall obstacles

R. den Otter[1] and A.E. Patla[2]

[1]Human Movement Sciences, University of Groningen, Groningen, Netherlands and [2]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: During goal directed locomotion we need vision to acquire environmental information necessary to select a path and walk safely to the intended goal. So far, research has focused primarily on the question how gaze fixations are tuned to environmental features (e.g. stepping stones, obstacles, traveling goals). However, it can be argued that the informational content of these features depends on task instructions and on the locomotor actions afforded by the specific actor environment interaction. As a consequence, even in identical environments, the preferred information may depend on what is considered most relevant within the given task context. Here we investigated whether a secondary task that requires visual control (i.e. carrying a plate filled with water) alters visual sampling strategies during walking in complex environments.
Methods: 6 healthy young subjects (22-31 yrs) were instructed to traverse a 12 by 8 grid with 12 tall (2.33 m) posts. Three grids configurations were used, each with 3 entrance and 2 exit points. Subjects had to traverse the grid under 3 conditions: (1) empty handed, (2) with an empty plate, and (3) while holding a plate that was filled with 220 ml of water. Fixations (stationary position of gaze for > 100 msec) were classified with respect to 5 possible locations: 'Posts', 'Travel path', 'Goal', 'Elsewhere' and (for conditions 2 and 3) 'Plate'.
Results: In the 'full plate' condition, subjects spent 44% of their total fixation time fixating the plate, compared to only 0.5% when the plate was empty (p<.05). As a consequence, the total time spent fixating posts, the travel path or the goal was significantly reduced in this condition (p<.05). The largest reduction in fixation time occurred in the goal fixations, from 43% and 46% in the empty handed and empty plate condition respectively, to 23% in the filled plate condition (p<.05). The mean duration of individual fixations was not significantly affected by the task (p>.05). Interestingly, in one individual case, fixations on the plate took up 93% of the total fixation time in the full plate condition.
Conclusions: The finding that the total time spent on fixating posts, the travel path, and the travel goal could be substantially reduced without compromising path selection suggests that portions of the visual information sampled during navigation are to some extent redundant. The selective reductions in fixation time on the travel goal in the 'full plate' condition suggests that gaze fixations served at least two distinct functions: i. identification of desirable and undesirable walking areas or surfaces (e.g. fixations on posts and the travel path necessary for path selection) needed for path selection, and ii. heading control (e.g. fixations on or behind the travel goal). The finding that total fixation time on environmental features was reduced to 7% in one individual shows that much relevant environmental information can be extracted from peripheral vision.

MP-77*

Duration of gaze fixations during locomotion around obstacles in a pathway

A.C. Novak, V. Miyasike-da-Silva and A.E. Patla

Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: Gaze fixations are related to the collection of information to perform tasks, such as walking. If a certain location is fixated upon for an increased amount of time when one is walking, this location might be a relevant source of visual information used to guide locomotion. This study aims to analyze the duration of gaze fixations during locomotion around obstacles in an environment with contrast restriction.
Methods: Six young adults were instructed to walk to a goal on a 7m long pathway under both high contrast and low contrast conditions, with varying number of turns required to avoid pylons (1, 2, or 3 turns) evenly distributed along the travel path. Participants performed 2 randomized trials under each condition combining the visual contrast and number of turns. Frame-by-frame analysis of the combined video data of the gaze and environment identified the gaze fixations. A fixation was determined when gaze stabilized on a location for three consecutive frames (~0.1s) or longer (Patla & Vickers, 1997). Mean duration of fixations and the total time fixating on the path, pylons, and goal were calculated. Additionally, both variables were analyzed separately for the fixations on pylons placed in the early, mid, and late segments of the pathway. One-way repeated measure ANOVAs were performed to verify the influence of the number of turns, the contrast conditions, and path segments on fixation duration. Significance level was set at 0.05.
Results: The mean duration of fixation was 0.236±0.077s and it was not affected by location, turns, contrast, or path segment (p > 0.05). Low contrast levels between pylons and background increased the total time spent in fixations (p<0.012). The total time fixated significantly increased only when three turns were performed compared to the other conditions with 1 or 2 turns (p<0.013). Individuals spent more time fixating on pylons than on any other location (p<0.002). The time fixating on pylons was different according to the path segment (p<0.002): participants fixated longest on pylons in the mid segment of the pathway followed by the late segment, and least, the early segment. To deal with the obvious effect of the number of pylons in the mid segment on the total fixation time, the total time in fixation on the mid segment was normalized by the number of obstacles in that path segment. Normalized values showed that the total time spent in fixations

were higher during both mid and late segments compared to the early segment.
Conclusions: Discussion and Conclusion: Although the duration of individual fixations are not affected by the variables manipulated in this study, the results suggest that people spend more total time fixating on locations that provide relevant visual information to guide their navigation, such as on obstacles and the goal, than elsewhere. As well, in order to successfully navigate in a travel path with multiple obstacles, increased visual information is required.(Support: NSERC, Capes-Brasil)

*Aging 2**

MP-9

De-coupling of gait parameters for stability improvements

D. Espy[1], Y. Feng[1] and C. Pai[1]

[1]Physical Therapy, University of Ilinois at Chicago, Chicago, IL, USA and [2]Movement Sciences, University of Illinois at Chicago, Chicago, IL, USA

Introduction: The purpose of this study is investigate the individual contributions of gait velocity and step length to risk of falling or of losing one's balance when slipped unexpectedly during gait. It is generally accepted that, as people age, their gait becomes slower and of shorter step-length and that both improve stability against balance threats. Recent studies have suggested that both shorter step length and faster gait velocity provide, individually, stability against a slip induced backward loss of balance. Since they are tightly coupled, the individual contributions of step-length and gait velocity to stability are unknown.
Methods: Fifty-seven healthy, young adults participated in this randomized, experimental comparison study. Methods: Subjects were slipped unexpectedly while walking on a runway at one of three target gaits: fast with long steps, slow with short steps, or slow with long steps. To allow comparisons, the velocity of the two slow gaits were equal while the step lengths of the two long step gaits were equal. Motion and force data were used to categorize each first slip as a fall, a loss of balance (LOB) or a non-LOB.
Results: Outcomes of fall, LOB, or no LOB were compared using chi-squared statistics. Results. Five of the 18 subjects in the slow velocity/long step-length group, but none of the 20 in the slow velocity/short step-length group, fell upon the first unexpected slip. This was significant at the .05 level. Eighteen of the 19 subjects in the fast velocity, long step length group experienced a LOB or fall at the first unexpected slip as compared to 25 of 38 in the two slow velocity groups(p=.08.)
Conclusions: At gaits of similar velocity, the subjects taking shorter step-lengths were less likely to fall upon initial slip than those with longer step-lengths. Subjects walking more quickly were more likely to lose their balance when slipped than those walking more slowly, regardless of steplength.

MP-10

Familiarisation to treadmill walking within virtual environments

M. Schellenbach[1], M. Lövdén[1], A. Krüger[2] and U. Lindenberger[1]

[1]Lifespan Psychology, Max Planck Institute for Human Development, Berlin, Berlin, Germany and [2]Institute for Geoinformatics, University of Münster, Münster, Nordrhein-Westfalen, Germany

Introduction: Assistive technology offers great promise for improving the quality of aging, but only if the design of devices is adapted to the needs of the user. We explore and evaluate the potential of assistive technology for counteracting negative effects of aging on pedestrian spatial navigation. Based on earlier work, we propose to transfer real navigation scenarios to a controlled and ecologically valid setting by means of virtual environments (VE) equipped with a walking interface. To this end, we use a treadmill with a floor-levelled walking area of 200 x 70 cm and a VE back-projected on a 270 x 200 cm power-wall in front of the treadmill. The Vicon motion analysis system is used to capture motion and allows for whole body motion capturing, and advanced biomechanical modelling. The use of treadmills rests upon the assumption that reliable and valid measures of gait can be obtained during treadmill walking and are comparable to gait measures of overground walking. Treadmill walking, in theory, is mechanically equivalent to overground walking, but in reality walking on a treadmill is initially an unfamiliar experience. In the present experiment we studied the amount of time required for treadmill familiarisation in younger and older adults. We also examined whether familiarised treadmill walking is similar to overground walking so that the results of treadmill walking experiments are likely to generalize to the real world. We hypothesised that both younger and older adults would familiarise to the treadmill and the virtual environment within one 20-min training session and that measures obtained from the treadmill following familiarisation could be generalised to overground walking.
Methods: We asked 17 younger adults (20-29 years) and 18 older adults (68-79 years) to perform an overground walking exercise as well as a treadmill-walking session. Participants had little or no previous exposure to treadmills and were reasonably healthy and fit. In a first session participants walked at self-selected speeds on the 30-m walkway 30 times with whole body motion captured each time over 7,5 m. After each 10 trials there were short breaks. The average preferred speed for each participant across six walking trials was calculated with the captured data. In the second session the treadmill speed was set at the preferred walking speed calculated for each participant. Participants walked freely on the treadmill for 20 min with a virtual environment projected in front of them. Data were captured during the whole trial after the treadmill reached the designated speed.
Results: Both age groups were able to adapt their gait to the treadmill and to the movement in the virtual world. Analyses of the captured data are underway to find out when this process is completed and if the gait pattern during treadmill walking can be generalised to overground walking.

Conclusions: Real navigation scenarios can be transferred to a controlled and ecologically valid setting by means of VE equipped with a treadmill.

MP-11

Measuring small changes in postural stability by using centre of mass feedback

J. Vanrenterghem, M. Hawken, G. Barton, M. Lake and A. Lees

Research Institute for Sport and Exercise, Liverpool John Moores University, Liverpool, UK

Introduction: Exercise has widely been reported to enhance postural stability. However, benefits have only been found where improvements were expected, e.g. in interventions targeting balance, and in the frail elderly (for secondary, or even tertiary prevention of falls). For generalised interventions and for less elderly adults no benefits have been found which has inhibited further investigation of this (e.g. primary interventions in the post-WWII baby boom generation). However, low sensitivity of measures of postural control may have led to significant occurrence of type II errors. A more sensitive measure may make it possible to demonstrate intervention effects.
Methods: A total of 11 active males (60.5±2.9 yrs, 83.5±12 kg, 1.75±0.07 m) took part in a 6-month trial of 30-minute walking-exercise performed 5 times per week. Initial intensity was set to correspond to 30% of heart rate reserve, and gradually increased every six weeks to 60% of heart rate reserve. A control group of 6 males (59.6±4.1 yrs, 90.6±9.1 kg, 1.81±0.04 m) received no intervention. Postural stability was measured pre- and post-intervention. The task consisted of controlling horizontal plane movements of a centre of mass representation (hCoM) derived from markers placed on the body (Vicon, full-body PluginGait). The hCoM was projected in real time on a screen in front of the subject. The subject stood on a 6DoF movable platform (Caren, Motek), was asked to keep the body straight and lean anterior-posterior and left-right to move the hCoM. Tasks lasted 20 seconds each and consisted of (A1) following a target moving clockwise around a circle (platform static); (B) as A1, but the circle diameter increased during the trial; (C) keeping hCoM on a central static target while the platform moved in combined pitch and roll; (D) as B, but with the platform moving; (A2) repetition of A1. The performance measure was the mean distance between hCoM and target (A-P and L-R components, and combined). Task A was repeated 5 times prior to the test for familiarisation. Three repetitions of each task were averaged. Repeated measures ANOVA was used for comparisons ($p < 0.05$).
Results: Subjects were able to perform each task, and no training effect was found within test sessions. After the intervention, performance of task A and C improved in both groups. Performance of task B improved more in the exercise group than in the control group. Performance of task D did not improve in either group.
Conclusions: Contrary to the findings of previous studies, a generalised walking intervention showed beneficial effects on dynamic balance. The method seems sufficiently sensitive to discriminate small differences in postural control. An important characteristic of the effect was the sensitivity to difficulty of the task (A and C were perhaps too easy, D too difficult). Discrimination provided by the method can be improved by refining the tasks (further directional differentiation) and by enhanced analysis of the data (movement frequency analysis).

MP-12

Can the time of stability on one foot combined with a passive antepulsion test detect hip-strategy use in the elderly and thus the risk of falling?

S. Villeneuve-Parpay, P. Villeneuve, P. Gagey and B. Weber

Institut de Posturologie, Paris, France

Introduction: Older persons are known to use a hip strategy to control their orthostatic posture (Woollacott, 1986) that can be detected quite simply by a clinical passive antepulsion test (PAT) (Villeneuve-Parpay et al, 2001). Moreover, the risk of an elderly subject falling can be predicted by a time of stability on one foot (TSOF) <5 s (Vellas et al, 1997). Could the PAT–TSOF relationship improve postural stability evaluation in the elderly and better assess the risk of a fall?
Methods: Thirteen professional podiatrists conducted these 2 clinical tests randomly, on their new patients over 50 years old who consented to participate in this study. TSOF was measured twice, first on the pillar foot (PF), which is spontaneously chosen as the first support, then on the motor foot (MF). TSOF measurement was arbitrarily stopped at 40 s. The PAT evaluates 4 responses: forward or backward movements of the pelvis, corresponding respectively to an ankle or hip strategy; anteversion, which negates the former, defines an intermediate response; and an uninterpretable response.
Results: The test results of 87 subjects (22 men and 65 women, respectively, 51–88 and 52–85 years old; mean ages: 68.6±10.1 and 69.3±8.1) could be interpreted: 24 used an ankle strategy, 48 a hip strategy, 15 an intermediate strategy. The percentage of these strategies differed as a function of TSOF <5 s or >5 s, independently of the support foot. When TSOF was <5 s, most of the subjects used a hip strategy; when TSOF exceeded 5 s, most of the subjects use an ankle strategy ($\chi 2$ test, $p<0.001$). In the larger female cohort, those using an ankle strategy were significantly younger than those using a hip strategy, and their TSOF, on the PF or MF, was significantly longer than that of the women using a hip strategy (Student's t-test for non-paired values: $0.0005<p<0.005$).
Conclusions: The older the subject, the more frequently a hip strategy was used; but this strategy was not directly linked to age. TSOF <5 s were significantly more frequent when a hip strategy was used, independently of the support foot. TSOF <5 s certainly does not mean the same thing for young subjects using an ankle strategy and elderly subjects relying on a hip strategy. Thus, associating a simple and rapid PAT with a TSOF <5 s, known be a good indicator of the risk of falling of an elderly subject, could improve the individual evaluation of this risk and our understanding of it. References : Vellas RJ, Wayne SJ, Romero IJ, Baumgartner RN, Garry PJ. Age Ageing 1997;26:189–93 Villeneuve-Parpay S, Villeneuve P, Weber B. Pied et posturologie. C Hérisson, J-Y Cornu, P Aboukrat, S Belhassen (eds). Montpellier: Sauramps Médical, 2001:175–83

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MP-13

Lateral stepping for postural correction in parkinson's disease

L.A. King and F. Horak

Neurosciences Institute, Oregon Health Sciences University, Beaverton, OR, USA

Introduction: Effective balance rehabilitation requires an understanding of how patients with balance disorders attempt to recover equilibrium in response to external perturbations. This study characterizes, for the first time, the lateral stepping strategies for postural correction in patients with Parkinson's Disease (PD) and the effect of their antiparkinson medication.
Methods: Thirteen subjects with PD in their ON and OFF levodopa state and 14 age-matched control subjects were exposed to 7 trials of 12 cm lateral platform translations toward their more involved side at 55cm/s. Three postural strategies were observed: lateral step (the limb loaded by the perturbation was unloaded and lateral base widened), cross-over step (the limb unloaded by the perturbation stepped over the front of the other foot) or no step (usually associated with a 'timber' fall). Corrective stepping was characterized by latency to step after perturbation onset, step velocity and step length. Additionally, percentages of trials resulting in falls were identified for each group.
Results: Whereas elderly control subjects never fell, PD subjects fell in 27% and 36% of trials in the ON and OFF states, respectively. Both PD and control subjects most often used a lateral step strategy; 70% (control), 64% (PD OFF) and 73% (PD ON) of all trials. PD OFF subjects fell most often when using a cross-over strategy (75% of all cross-over trials) or no-step strategy (100% of all no-step trials). PD OFF subject's lateral stepping strategies were initiated later than controls (370+37 vs. 280+10 ms; $p<.01$), and steps were smaller (254+20 vs. 357+17 cm; $p<.01$) and slower (0.99+0.08 vs.1.2+0.07 cm/sec; $p<.05$). No differences were found between PD OFF versus PD ON in the corrective stepping characteristics. Late steps were associated with falls with a correlation of 0.79, $p>0.01$. Levodopa medication did not significantly affect falls, lateral step latency, velocity or amplitude ($P>.05$).
Conclusions: PD subjects showed significantly more postural instability and falls than age-matched control subjects when stepping was required for postural correction in response to lateral disequilibrium. Although PD subjects usually chose the same lateral stepping strategy as age-matched control subjects in response to lateral translations, bradykinetic characteristics of the stepping responses help explain the greater rate of falls in subjects with PD. Unlike control subjects, PD subjects were unable to maintain equilibrium when using a cross-over strategy and sometimes failed to take a step at all and fell. Levodopa replacement therapy did not change either strategy selection, stepping characteristics or number of falls, suggesting that levodopa does not improve lateral stepping responses, similar to in-place postural responses. Rehabilitation aimed at improving lateral stability in PD should encourage a lateral side-stepping strategy with faster and larger steps to recover equilibrium. This study was supported by NIH-AG 006457

MP-14

Investigation of the Spatio-Temporal Parameters and Cardiorespiratory Responses during the 6-Minute Walk Test in Healthy Elderly Subjects

C. Hovington[1], S. Nadeau[2] and A. Leroux[1]

[1]Exercise Science, Concordia University and Centre de Recherche Interdisciplinaire en Réadaptation du Montréal Métropolitain - Constance-Lethbridge Rehabilitation Center, Montréal, QC, Canada and [2]Faculté de médecine- École de réadaptation, Université de Montréal and Centre de Recherche Interdisciplinaire en Réadaptation du Montréal Métropolitain - Institut de réadaptation de Montréal, Montréal, QC, Canada

Introduction: The 6-minute walk test (6-MWT) has been widely used in research, with a focus being placed on spatio-temporal parameters while little emphasis has been placed on physiological parameters of this submaximal exercise test. Even though it has been reported that the distance walked during the 6-MWT decreases with age, the adaptation of cardiorespiratory functions to such exercise has received very little attention. The primary objective of this study is to compare and contrast the changes in spatio-temporal and cardiorespiratory parameters during the 6-MWT in healthy elderly subjects aged between 60-69 years and 70-79 years. A secondary objective is to identify cardiorespiratory parameters and functional performance variables that best predict the total distance covered during the 6-MWT.
Methods: Two cohorts (60-69 and 70-79 years of age) of 10 healthy community-dwelling subjects performed the 6MWT on three occasions over 2 days (2 practice trials and 1 recording session) while wearing a portable metabolic measurement system (Cosmed k4 b2, Rome, Italy). The distance, walking speed, heart rate (HR), and oxygen uptake (VO2) were measured during the 6MWT. In addition, subjects performed the Timed-Up-and-Go test (TUG) and the Human Activity Profile (HAP) as functional performance measures.
Results: The 60-69 cohort covered a significantly ($p < 0.05$) greater distance during the 6MWT than the 70-79 cohort (618 ± 49.5 m vs. 557.5 ± 74.5 m), representing a 9.9% difference. The VO2 reached during the steady-state period (between min 3 to 6) was also significantly ($p < 0.05$) greater for the 60-69 cohort (19.9 ± 3.1 ml.min-1.kg-1) than for the 70-79 cohort (16.7 ± 3.7 ml.min-1.kg-1). In contrast, no significant differences were found for HR values during the steady-state period. Correlational analyses of the combined cohorts revealed that the subjects' age, VO2 in steady-state period, TUG time and HAP score were significantly related to the 6MWT distance with r values of -0.60, 0.73, -0.65 and 0.50, respectively.
Conclusions: The results showed that the older cohort of subjects performed the 6MWT at a slower pace and with a decreased oxygen uptake than the younger one. In addition to the aging process, other factors like the physical activity status and the functional mobility level can influence the distance covered by healthy elderly subjects during the 6MWT.

MP-15

Effects of a Gaze Behaviour Intervention on Stepping Accuracy of Older Adults

W.R. Young and M.A. Hollands

School of Sport and Exercise Sciences, University of Birmingham, Birmingham, UK

Introduction: It has previously been demonstrated that young adults and older adults at low risk of falling, usually maintain gaze on a stepping target until after their foot has landed on it. In contrast, high-risk older adults transfer their gaze away from a target significantly earlier than low-risk elderly or young adults (Chapman GJ & Hollands MA (2006) Gait & Posture Aug 26; Epub ahead of print). This behaviour, associated with a decrease in the accuracy and precision of stepping, is only seen when multiple targets are present in the travel path. The authors proposed that a premature shift of attention towards future targets may represent an inappropriate prioritization of the planning of future movements over that of ongoing stepping actions. The aim of the current study was to test if the gaze behaviour exhibited by high-risk older adults can be altered, via intervention, to more closely resemble that of low-risk older adults and young adults and to observe any corresponding changes in stepping performance.

Methods: Ten high-risk older adults (>65 yrs) were randomly placed into either a control or intervention group. All participants were screened for deficits in visual, motor and cognitive functioning and mental health was assessed. Participants were required to walk a 10m travel path which contained three stepping target and obstacle sub-tasks: 1) a single target box 2) two target boxes 3) two target boxes separated by an obstacle. Participants were instructed to walk at their own pace and place their feet as accurately as possible into the centre of each target. Participants completed 20 trials in each condition, presentation of which was randomized. Gaze and lower limb kinematics were measured using a Vicon system interfaced with an ASL500 gaze tracker. On a separate day participants returned and repeated the experiment. The intervention group where given additional instruction to maintain their gaze on a target box until after their foot had landed inside it. The control group completed a second session under the same instructional conditions as the first.

Results: Preliminary results show that our intervention produced a significantly greater reduction in A-P foot placement error than that obtained under control conditions (12.6mm cf 6.8 mm). Interestingly, some participants found the gaze behaviour requirements for the intervention unachievable and continued to transfer their gaze away from the first box before heel contact.

Conclusions: These preliminary findings suggest that improvement of foot placement accuracy is achievable through the manipulation of visual behaviour and support the proposal that premature redirection of gaze towards future stepping constraints may contribute toward the increased incidence of elderly falls. Analysis of the effects of the intervention on performance in subsequent steps (obstacle and second target) will hopefully shed light on the mechanisms underlying high-risk older adults' adoption of an apparently adverse visual sampling strategy.

MP-16

Coordinating changes in walking direction following hemiparetic stroke

K.L. Hollands[1], P.M. van Vliet[1] and A.M. Wing[2]

[1]School of Health Sciences, University of Birmingham, Birmingham, UK and [2]School of Psychology, University of Birmingham, Birmingham, UK

Introduction: The ability to change walking direction in response to environmental demands is essential for avoiding obstacles and reaching a desired destination. In healthy individuals this involves proactive coordinated reorientation of body segments towards the future direction of travel. First the head is aligned, followed by the upper body and finally the feet. Stroke patients demonstrate altered temporal and spatial inter-segmental coordination patterns during straight walking. However, how stroke survivors adapt an already altered coordination pattern to change direction is undocumented. The purpose of this investigation was to describe full-body kinematics of stroke survivors performing both pre-planned and reactive direction changes while walking and to determine if hemiparetic walkers can adapt walking patterns to accomplish a direction change at short notice.

Methods: Participants (6 stroke survivors & age-match controls) were asked to walk at a self-selected pace along one of 3, 6m routes; a straight travel path, or travel paths with a 45 degree turn to the right or left. Participants were cued to follow a route either from the start of the walk (early cue, EC) or mid-way through the start of a straight walk (late cue, LC). In LC, participants were required to either continue walking straight or change direction. Direction cues were given using lights placed at eye level at the end of each route. Lights were triggered when participants stepped on a pressure sensitive mat located 2 steps before a direction change was required. Full-body kinematics (36 marker set-up) were collected using a Vicon MX over the course of 40 trials (5 trials for each direction change under each cue condition + 10 trials of straight walking under each cue condition).

Results: Table 1 presents preliminary data from 3 patients and indicates the head leads the foot into the turn but there is near simultaneous turning of head and thorax with some differences between LC and EC .

Conclusions: Hemiparetic stroke participants were able to adapt walking patterns to change direction at the short notice however temporal coordination between head, thorax and foot segments was altered when turning to the paretic side. They demonstrated an en-bloc style of segment reorientation between head and trunk when changing direction towards the paretic side regardless of the amount of time provided to plan and implement the turn.

Table 1: Difference between head, thorax and ipsilateral-foot onset latencies of medial-lateral displacement

	LC		EC	
	Head-thorax (s)	Head-foot (s)	Head-thorax (s)	Head-foot (s)
Patient 1	.01 (.09)	.53 (.61)	.03 (.07)	.95 (.30)
Patient 2	.02 (.09)	.46 (.44)	-.03 (.12)	.40 (.56)
Patient 3	.04 (.06)	.57 (.46)	.01 (.07)	.80 (.47)

Onset latencies of segment medial-lateral displacements in the new direction of travel for the Late Cue (LC) and Early Cue (EC) conditions [mean (SD)]

MP-17

Age-related differences in procedural motor learning of a novel balance task involving unpredictable oscillations of the support surface

K. Van Ooteghem[1], J.S. Frank[1], F. Allard[1] and F.B. Horak[2]

[1]University of Waterloo, Waterloo, ON, Canada and [2]Neurological Sciences Institute, Oregon Health and Science University, Beaverton, OR, USA

Introduction: Previous work has reported age-related deficits in procedural motor learning [1] and balance control [2]. Our study aimed to determine older adults' capability for improvement in a balance task. In detail, the purpose of this study was to examine the effects of age 1) on the ability to benefit from practice with seemingly unpredictable perturbations and 2) on the postural coordination strategy used to maintain balance under these conditions.

Methods: Eleven, healthy older adults were instructed to maintain their balance while standing on a translating platform that underwent random amplitude and constant frequency (0.5 Hz) oscillations. Trials were 45 seconds in duration, composed of three, 15-second segments. The middle segment of each trial contained the same sequence of oscillations but participants were not informed of this feature of platform motion. Participants completed a practice session on day one (42 trials) and a retention test on day two (7 trials).

Results: Kinematic measures of body movement revealed that centre of mass (COM) displacement ratios were similar for young and older adults early in training. With practice, young adults were better able to control their COM but older adults did not demonstrate significant decreases in COM displacement ratio despite self-report that the task was becoming easier. Joint angle correlations with platform motion revealed that young adults evolved from an ankle strategy to a multi-segment coordination pattern involving the ankle and hip while older adults maintained an ankle strategy with flexion at the knee. Ankle joint correlations were negative and increased for both young and older adults while only young adults demonstrated hip correlations that improved with practice. Segment specific differences were not observed for young adults but data from older adults revealed differences in ankle joint correlation between random and repeated sequences.

Conclusions: With practice, older adults were better able to follow platform motion but improvements at the ankle joint did not translate into improved balance control. Unlike young participants, older adults did not demonstrate an evolution in the complexity of their postural control strategy; maintaining an ankle strategy throughout training. This pattern of control resulted in differences between random and repeated segments that were not observed in young adults who adopted a multi-segment coordination pattern. These differences; however, did not lead to differential improvements in balance control suggesting that this feature of platform motion was not beneficial to performance. 1. Seidler RD (2006). Differential effects of age on sequence learning and sensorimotor adaptation. Brain Research Bulletin, 70: 337-346. 2. Horak FB, Shupert CL, Mirka A (1989). Components of postural dyscontrol in the elderly: a review. Neurobiology of Aging, 10(6): 727-738.

MP-18

Recovery of head and trunk coordination after stroke

G. Verheyden[1], A. Ashburn[1], M. Burnett[1], J. Lawrence[1], N. Shepard[2], D. Taylor[3] and .. on behalf of the STARR team[1]

[1]The Stroke Association Rehabilitation Research Centre, School of Health Professions and Rehabilitation Sciences, University of Southampton, Southampton, UK, [2]Department of Special Education and Communication Disorders, University of Nebraska - Lincoln, Lincoln, NE, USA and [3]Health and Rehabilitation Research Centre, Faculty of Health and Environmental Sciences, Auckland University of Technology, Auckland, New Zealand

Introduction: Studies in healthy individuals have described a clear sequence of head and trunk coordination during horizontal gaze transfers that require whole body movements. For patients after stroke, there is evidence to suggest that sensorimotor integration of postural adjustments and voluntarily head movements may have been modified. The aim of our study was to examine head and trunk coordination, in particular movement initiation in people early after stroke.

Methods: We evaluated 6 people with stroke and 6 healthy controls. Subjects with stroke were assessed clinically and in a laboratory setting at three, six and 12 weeks after stroke. Control subjects were also examined at three consecutive time points with the same weekly interval as the stroke group. Participants were asked verbally to rotate their head to the side of preference and look at a visual signal placed at 90° left and right from centre. Markers were attached at standardised positions of the body and 3-D motion recordings were made using CODAmotion. Data analysis consisted of examining the sequence of head and trunk rotation in both groups separately using Wilcoxon signed rank test. Differences in degree of head rotation, shoulder rotation and delay in rotation were analysed between groups and over time by means of Wilcoxon ranked sum test and Friedman analysis respectively.

Results: The pattern of movement demonstrated by the healthy controls (2 females, 4 males, median (IQR) age 64 (62-70) years) at all three time points showed rotation of the head before rotation of the shoulders ($p=0.028$). In comparison, the mildly impaired stroke group (1 female, 5 males; median (IQR) age 70 (65-79) years) showed no significant difference between rotation of the head and shoulder at three weeks after stroke ($p=0.075$). This pattern changed over time, reflecting the sequence demonstrated by the healthy controls, with a significant start of rotating the head before the shoulders both at six weeks ($p=0.046$) and at 12 weeks ($p=0.028$) after stroke. When comparing both groups at the three time points, there was no significant difference in degree of head rotation, shoulder rotation or in delay in rotation. However the stroke group had a relatively smaller variability in degree of head rotation and a larger variability in degree of shoulder rotation in comparison to the healthy controls. The results of the Friedman test with post-hoc analysis showed a significant decrease in degree of head rotation for stroke patients between three and 12 weeks after stroke ($p=0.028$).

Conclusions: We believe this is the first study to evaluate recovery of the sequence of head and trunk coordination during the acute stages following stroke. Our results suggest that people with stroke show a modified coordination pattern early after stroke but recover over time towards the level of healthy subjects. Future research should include more impaired stroke patients as well as evaluate the relation with clinical measures and thus importance in everyday activities.

MP-19

THE EFFECTIVENESS OF TWO TYPES OF BALANCE-BOARDS TO IMPROVE ELDERLY BALANCE OVER AN 8-WEEK TRAINING INTERVENTION

Y. Lajoie and B. Contant

Human Kinetics, University of Ottawa, Ottawa, ON, Canada

Introduction: It is known that elderly who fall can suffer serious injuries. The American Geriatrics Society Panel on Falls Prevention has included in its specific recommendations for single interventions "exercise including a component of balance training"(2001). Studies have shown that training programs such as tai chi, biofeedback, and virtual reality training can improve balance in elderly people. (Hu et al., 2004; Hamman et al., 1995; Bisson et al., In Press). Adequate motor control at the ankle plays an important role in maintaining equilibrium (Waddington et al. 2004). In the past wobble-boards have been used to successfully rehabilitate patients with ankle injuries. For the elderly population, wobble-boards have been shown to improve ankle proprioception but have never been used specifically to improve balance with the goal of fall prevention. The objective of this study is to compare the effectiveness of two types of balance-boards (wobble-board and rocker-board) to improve balance in older adults. The focus of the study is to measure any changes to functional balance, attention while performing two tasks (maintaining balance and verbal reaction time) and postural sway during quiet standing.

Methods: Twenty-eight healthy elderly, 12 in the wobble-board group (age = 72.9 ± 4.62), 11 in the rocker-board group (age = 73.5 ± 4.08) participated in an 8-week intervention consisting of three sessions per week, 20 minutes each session. There were 5 elderly in the control group (age = 76.2 ± 5.49). Participants were required to show mental competence by achieving a passing grade of 25 points on a mini-mental state evaluation. They also had to be autonomous with the ability to walk without aid. Baseline, post-training and retention measures of functional balance (CB&M), attention and postural sway were collected.

Results: Following the intervention experimental groups had significantly improved their functional balance scores. The wobble-board group improved by 11 points between baseline and post-training which is more than double the score needed to satisfy a significant clinical improvement according to Inness & Howe (2002).The rocker-board group also showed a significant improvement of 6 points. The control group showed no improvement. The experimental groups' attentional demand improved between baseline and the post-test. Finally, postural sway results during quiet standing showed no improvement for either group ($p > 0.05$).

Conclusions: Wobble-board training seems to be an effective tool for improving functional balance needed for daily activities. Results show that balance-board training effectively improves dynamic balance and attentional demands of healthy elderly people. This suggests that making balance-board training a part of an exercise program can improve activities of daily living. Furthermore, training on a balance board may free attention normally used when standing to process other information in the environment.

MP-20

Bilateral coordination of gait is reduced with age and compromised in Parkinson's disease

M. Plotnik[1], N. Giladi[2] and J.M. Hausdorff[1]

[1]Movement Disorders Unit, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel, [2]Neurology, Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel, [3]Physical Therapy, Sackler School of Medicine; Tel Aviv University, Tel Aviv, Israel and [4]Division on Aging, Harvard Medical School, Boston, MA, USA

Introduction: Mechanisms underlying bilateral coordination of gait in human subjects are not fully understood. Recently we described that patients with Parkinson's disease (PD) who suffer from freezing of gait (FOG), have reduced ability to coordinate left/right stepping. In this study, our objective is to characterize the effect of age and PD stages on the level of bilateral coordination of gait.

Methods: Methods: We examined the gait of young adults (n=15), elderly subjects (n=11), PD patients in mild stage of the disease (n=20), PD patients in advanced stage of the disease that do not suffer from FOG (PD-FOG, n=13) and PD patients in advanced stage of the disease who suffer from FOG (PD+FOG; n=21), during straight line normal walking (i.e. freezing episodes were excluded if occurred). PD patients in sever stage of the disease were tested both "Off" and "On" L-dopa medication. Subjects wore force sensitive insoles that recorded the timing the events within the gait cycle. 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 and the mean absolute difference between ϕ and 180° was defined as the Phase Coordination Index (PCI), representing variability and inaccuracy, respectively, in phase generation.

Results: PCI values varied between the groups. Young adults had the lowest mean values, and PD+FOG patients in "Off" state had the highest mean value. See table for detailed results.

Conclusions: In healthy subjects, left/right coordination of stepping becomes more variable and less consistent with age. Distinctive impairments in the bilateral coordination of gait exist among PD patients and aggravate with the progression of the disease. FOG in PD is related to extreme aggravation in bilateral coordination of gait.

Means (SE) values of PCI (%)

Group	PCI	Statistical comparison
PD+FOG Off	15.1 (3.4)	PD+FOG Off Vs. PD-FOG Off P=0.024
PD+FOG On	9.9 (1.8)	PD+FOG Off Vs. PD+FOG On P=0.059
PD-FOG Off	7.3 (0.7)	PD-FOG Off Vs. PD-FOG On P>0.9
PD-FOG On	7.0 (0.9)	PD+FOG On Vs. PD-FOG on P=0.4
Mild PD On	5.6 (0.6)	Mild PD On Vs. Sever PD On (+FOG&-FOG) P<0.025
Elderly	3.3 (0.2)	Mild PD On Vs. Elderely P=0.032
Young Adults	2.5 (0.1)	Young Vs. Elderely P=0.019

MP-21

Age-related differences in reach-to-grasp reactions and associated gaze behavior evoked by unexpected perturbation when walking in an unfamiliar environment

T. Lee, C. Scovil, S. McKay, A. Peters and B. Maki

Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada

Introduction: To grasp a handrail, the CNS requires visuospatial information (VSI) about the target location. However, for compensatory reach-to-grasp reactions triggered by sudden loss of balance, the urgent need to react rapidly severely limits opportunity to scan the environment after perturbation onset (PO). Recent studies of young adults suggest that the CNS instead relies on 'stored' VSI that is acquired and updated automatically as the person moves about. Age-related deficits in VSI processing may interfere with ability to acquire this information and incorporate it into the control of rapid reaching reactions. In this study, we test a hypothesis that older adults (OA) are more likely than younger adults (YA) to make errors in executing compensatory reaching reactions, and we explore age-related differences in the associated gaze behavior.
Methods: Compensatory reaching reactions were evoked in healthy YA (age 20-30) and OA (age 65-75) using an extended (2x6m) motion platform. This platform was configured to simulate an office environment, including a stair, handrail and various visual distracters. A door prevented viewing of the environment prior to the start of the trial. The subject was given the task of making a phone call, which required opening the door and walking to the far end of the platform to access the phone. The platform was triggered to move suddenly as the subject approached the rail. A deception was used to ensure that the perturbation was truly unexpected. To prevent learning and adaptation, subjects performed only one trial, which was their very first exposure to the perturbation and environment. Measured outcomes included gaze behavior, arm kinematics and muscle-activation timing.
Results: To date, five of ten YA and two of ten OA have been tested. Three YA grasped the rail successfully in response to the perturbation; the other two reached toward the rail but did not attempt to grasp it. One of the OA initially overshot the rail, but was subsequently able to grasp it successfully; the other OA did not reach for the rail. Both age groups made numerous saccades and fixations upon entering the unfamiliar environment. Four of the five YA fixated on the rail during one or more intervals prior to PO, but none looked at the rail after PO. The OA who overshot the rail failed to look at the rail prior to PO, but did fixate on the rail during subsequent efforts to grasp the rail. Results from the full cohort will be presented at the meeting.
Conclusions: Although the full cohort is needed to draw definite conclusions, these preliminary results are consistent with the hypothesis that OA would be more likely than YA to make errors in grasping the rail. Furthermore, the errors appear to be related to a failure to fixate on the rail prior to PO. The results support the idea that 'stored' VSI is used to initiate the reaction. 'Online' visual control appears to be limited to corrections during the prehension phase. Funding: Canadian Institutes of Health Research

MP-22

Does the pattern of gait change when growing older?

W. Wong, Y. Shibata, M. Yin and K. Ishikawa

Department of Sensory Medicine, Division of Otorhinolaryngology, Head and Neck Surgery, Akita University School of Medicine, Akita City, Akita Prefecture, Japan

Introduction: Integration of normal equilibrium function, space orientation and cognitive function are needed to complete a straight line or circular walking. Also, visual and vestibular inputs play important roles in a constantly varying 3 dimensional environment to perform a smooth locomotion. However, during aging process, most elderly people suffer problems on gaiting and falling which eventually affect the activity of daily life. To understand physiologically, how aging might defect the stability of gait, normal individuals (young and elder groups respectively) were studied walking on straight line and circle (radius, r=0.5m) under eyes-opened and blindfolded conditions by means of gait analysis using tactile sensors.
Methods: 18 normal individuals (young group, average age: 25.8 y.o; elder group, average age: 59.8 y.o) were enrolled and gait analysis using of tactile sensors installed under both feet were performed. Mean time length 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 between two groups when walking on straight line neither under eyes-opened nor blindfolded conditions. However, longer duration of mean double support was found on elder group for both clock- and counterclockwise circular gaits compared to young group, under eyes-opened or -closed conditions. The CVs of stance were significantly greater in elder groups (eyes-opened and -closed) compared to young group in circular gait. On clock-wise circular gait (eyes-opened condition), CV of stance (right foot) is greater and on counterclockwise circular gait (eye-opened condition), CV of stance (left foot) is greater in elder group. On the other hand, the same group showed different result under blindfolded condition on counterclockwise circular gait, that is greater CV of stance (left foot); and on clock-wise circular gait, greater CV of stance (right foot).
Conclusions: Older individuals showed difficulty in completing a circular gait, even though they did not seem to have problem walking on straight line. Circular gait generates more vestibular input of the innermost ear to the circle. Despite of the visual input, the degeneration of vestibular function due to aging, might be the most probable answer to this study.

MP-23

Hip pull-off and ankle push-off in healthy adult gait

O. Sofuwa, A.M. Ashburn, E.L. Stack and V.T. Yule

School of health professions and rehabilitation sciences, University of Southampton, Southampton, UK

Introduction: This study is the first phase of the study into the ankle and hip function in the gait of people affected with Parkinson's disease (PD). The aim was to design a gait analysis laboratory protocol that can be used to characterise the gait of healthy adult and later used for the study of PD gait. This was primarily by measuring and describing the gait events of hip pull-off and ankle push-off during the late stance/preswing phase of the healthy adult gait cycle.
Methods: Thirteen healthy adults with mean age, height and weight of 65.5±6 years, 1.63±0.1, 75±8.8 respectively participated in the laboratory based study. A laboratory session was conducted per subject and it consisted of trials in which each subject walked back and forth in their usual manner along an eight-meter walkway. Their gait was measured by using a camera based motion analysis system (CODA) and a force platform that was situated on the walkway. The events with use of the laboratory protocol were reported whilst the gait analysis outcome measures used to describe the events of pull-off and push-off were the functional gait parameters such as the kinetic, kinematic and the spatiotemporal. Overall, thirteen laboratory sessions were conducted that consisted of 225 trials out of which 111 trials had force platform data and 55 trials were selected that met with the selection criteria for final analysis. Identified issues such as pelvic marker obstruction (by the arm) and not aiming to step on the force platform also affected number of trials finally selected.
Results: Gait analysis using the selected trials showed that the healthy subjects walked with a mean peak hip pull-off power and peak ankle push-off power of 0.85±0.37W/kg and 2.63W/kg respectively. These values were comparably within range measured in previous studies for hip pull-off power (0.88-1.34W/kg) and ankle push-off power (1.70-2.90W/kg). The associated joint angular excursion during hip pull-off and ankle push-off were 9.02±3○ and -24.18±6○ respectively. The findings at the knee showed that during late stance, the subjects had a mean peak absorption power of -0.78±0.41W/kg which was comparable to -0.63-0.90W/kg of previous studies. The associated change in knee flexion was 36.50±3○.
Conclusions: The main conclusion is that the pull-off and push-off powers at the hip and ankle joint respectively were within the range measured in previous study whilst the associated joint angular excursion which were not previously measured during pull/push-off contributes to the database of gait of healthy adults of the same age range. The laboratory protocol was satisfactorily used in this study to analyse the gait of the healthy subjects. With some modification to the procedure of subject and laboratory set up, the protocol can be suitably used in the study of PD gait.

MP-78*

Effects of deteriorated sensory information on the kinetics and kinematics of sit-to-stand in young and older adults

N. Deshpande, A. Novak[1] and A.E. Patla[2]

[1]Queen's University, Kingston, ON, Canada, [2]University of Waterloo, Waterloo, ON, Canada and [3]University of Kansas Medical Center, Kansas City, KS, USA

Introduction: Sit-to-stand (STS) is a commonly performed human movement and is crucial for independence of elderly persons. We examined the effects of deteriorated sensory inputs on the global, kinetic and kinematic parameters of STS in young and older adults.
Methods: From the sitting position, young (Y-A) and elite older (O-A) adults (n=6) were asked to stand up as quickly as possible under two lower limb proprioceptive conditions, 1. Normal input: on hard surface (HS) and 2. Inaccurate input: on compliant surface using medium density foam (CS); and three vision conditions 1. Normal vision (V), 2. Blurred vision simulating cataract (using custom-made blurring vision goggles, BV), and 3. Eyes closed (no vision, NV). The participants were not allowed to use their hands for support. The time to complete the transition phase of STS (TransTime), peak breaking force (PBrF) and magnitude and time-to-achieve peak horizontal (ant-post) and vertical momentum were measured.
Results: TransTime was more in O-A (p=0.02). Further, the increase in TransTime on CS was also more in O-A (Y-A: 13%, O-A: 38%). Vision manipulation had no effect on TransTime in Y-A. In contrast, in O-A, TransTime increased in NV condition, irrespective of the surface condition (p=0.044). PBrF was less in O-A (p=0.018) and it reduced further when vision was absent (p=0.005). Similar effect was also found in Y-A, however, only on CS (p=0.042). There was no effect of age, surface or vision condition on the magnitude and time-to-achieve peak horizontal momentum. In contrast, peak vertical momentum was less in O-A (p=0.044) and decreased further on CS (p=0.023). Vision manipulation had a marginal effect (p=0.052). In O-A, peak vertical momentum was achieved significantly later on CS (p=0.006).
Conclusions: Results suggest that the global performance during the transition phase is dependent on the available sensory information, particularly in older adults. Spending longer durations in this highly destabilizing phase may increase the risk of falling during STS. Lower magnitude and longer time-to-achieve peak vertical momentum in older adults could be due to weakness of lower limb (LL) muscles and slower development of muscle forces. Additional effects of sensory manipulations on these parameters need investigation. It is possible that the challenges posed by deteriorated sensory conditions resulted in co-contractions of LL muscles (Benjuya et al., 2004) that further reduced the efficiency of performance. A tight regulation of the magnitude and the time required to achieve the peak horizontal momentum supports the proposed invariant characteristics of horizontal parameters during STS (Vander Linden et al., 1994). However, lower PBrF in the elderly in deteriorated sensory conditions indicates inefficiency in reducing horizontal momentum to terminate the transfer. In conclusion, there is a

significant decline in the adaptive capacity of the central nervous system to suboptimal sensory inputs during STS even in elite older persons.

MP-79*

Influence of hallux valgus on postural stability when walking in older adults

E. Nerozzi[1], T. Patla[2], M. Ishac[2] and J.S. Frank[3]

[1]Facoltà di Scienze Motorie, Università degli Studi di Bologna, Bologna, Italy, [2]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada and [3]Faculty of Human Kinetics, University of Windsor, Windsor, ON, Canada

Introduction: Hallux valgus is a common foot deformity in older adults. This deformity can compromise postural stability when walking by decreasing the mechanical stability of the foot and/or proprioceptive sensations from the foot. We examined the influence of hallux valgus on the postural stability of older adults when walking under conditions that a) increased the mechanical stress on the foot and b) increased the dependence on foot proprioception.
Methods: Twenty women, 60-75 years of age, participated in the study. Ten participants had a hallux valgus deformity of the foot, defined as a deviation of the first metarsal joint of the large toe of greater than 15 deg, and 10 age-matched participants did not have this condition. Participants were required to walk barefoot a distance of 6 meters under the following conditions: 1) normal walking, 2) fast walking, 3) wide-stance walking at normal speed, 4) wide-stance walking at fast speed, 5) normal walking with eyes closed and 6) fast walking with eyes closed. Conditions 1-4 varied the mechanical stress on the foot. Conditions 5 and 6 increased the dependence on foot proprioception. Limb kinematics and trunk centre of mass (COM) were derived from recordings of 21 markers positioned on the limbs, trunk and head using a high-resolution motion analysis system (Optotrak).
Results: Trunk stability was similar for participants with and without hallux valgus during normal walking and remained similar when increasing the mechanical stress on the foot with fast and wide walking. When increasing dependence on foot proprioception by walking with eyes closed, both groups showed greater medial-lateral motion of the trunk; however, this increase was greater for the normal group than the group with hallux valgus. Step length, width and double-support time were similar across all walking conditions for participants with and without hallux valgus. Single-support time was general shorter for participants with hallux valgus than those witho this foot deformity.
Conclusions: The foot deformity of hallux valgus does n appear to disrupt postural stability when walking at normal spee or when increasing the mechanical stress on the foot during fa and wide-stance walking. Increasing dependence on foot pr prioception by walking with the eyes closed revealed a differen in medial-lateral trunk stability for the two groups. While bo groups increased medial-lateral motion of the trunk under t eyes-closed condition, the increase was greater for those wit out hallux valgus than those with hallux valgus. The more lin ited motion of the trunk in participants with hallux valgus may reflect a strategy of stiffening the trunk to compensate for decreased contribution of foot proprioception to monitoring postural stability.

*Rehabilitation and Training**

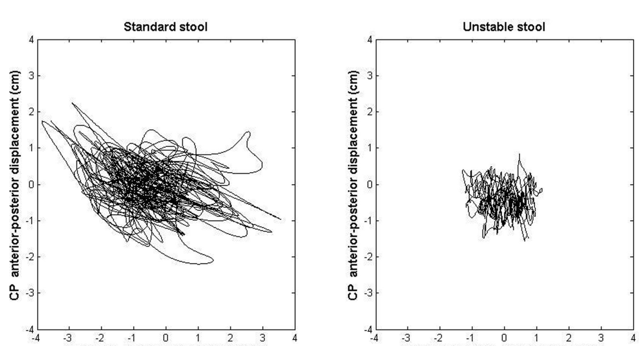
MP-24

An unstable stool for reducing body oscillations and trunk EMG activity in musicians

F. Berrigan[1], M. Simoneau[1], U. Stuber[2], N. Leclerc[2] and N. Teasdale[1]

[1]Kinésiologie, Université Laval, Québec, QC, Canada and [2]Musique, Université Laval, Québec, QC, Canada

Introduction: Several epidemiological studies have highlighted that musicians can be affected by musculoskeletal problems (eg. Lederman, 2003). Nevertheless, there is a scarcity of experimental research to examine and propose preventive measures for this population. The aim of this study consisted of examining whether an unstable stool could reduce the amplitude of the upper body oscillations and the overall activity of trunk muscles.
Methods: Twelve active professional musicians performed the same partition (90 bpm; 10 trials of 35 s) on a standard stool and on an unstable stool. Stability measurements were acquired using a force platform. Trunk and leg muscles activity (EMG) and kinematics of the upper and lower body were also measured (Selspot II).
Results: Figure 1 shows center of pressure displacement (CP) for the anterior-posterior and medio-lateral axes for one subject. For all musicians, using the unstable stool yielded a significant decrease of the range of postural oscillations (3.15cm and 2.6cm, for the anterior-posterior and medio-lateral axes, respectively). The EMG activity of trunk muscles was smaller when performing on the unstable stool. Muscular torque, calculated using inverse dynamics, also showed a significant reduction.
Conclusions: According to the musicians, using the unstable stool did not perturb their performance. Using the unstable stool within daily practice regime could help to adopt better and less stressful postural attitudes. Reducing upper body oscillations when playing a string instrument could be a mean to decrease the prevalence of musculoskeletal disorders among this population.



MP-25

Effect of 6-week Tai Chi training on balance performance in children

Y. Nien[1], L. Chuang[2] and S. Chang[3]

[1]Institute of Coaching Science, National College of P.E. & Sports, Taoyuan, Taiwan, [2]Department of Chinese Martial Arts, Chinese Culture University, Taipei, Taiwan and [3]Department of Exercise Science-Martial Arts, Taipei Physical Education College, Taipei, Taiwan

Introduction: Previous research has demonstrated that Tai Chi, one of mind-body exercise based on Chinese martial art, can improve or maintain balance ability. However, most of the studies focus on older or elder adults, and few studies have examined the effect between Tai Chi training and balance performance in children. The purpose of this study was to assess the effect of Tai Chi training on balance performance in children.
Methods: Elementary school students (n=20, age M= 10.7±0.87 years) were recruited for participation in a 6 week exercise trail. In addition, participants were randomly assigned to either Tai Chi Group (n=10) or control group (n=10). Exclusion criteria included history of severe heart disease, vertigo, epilepsy, and any eye, limb injuries within six months prior this study. Tai Chi group instructed 24 forms of standard Tai Chi movement used for the Asian teenager Tai Chi competition and the control group participated in general physical education course for six weeks (1 hour/day, 2 days/week). Three balance tests, one leg standing with eyes closed test, static balance test, and dynamic balance test (static and dynamic balance test were used K.A.T. 2000 balance system) were measured before and after six weeks training on both groups. Independent t-tests were computed by SPSS for mean differences between two groups, and alpha was set at .05.
Results: There was no statistically significant difference in baseline data (age, height and weight) between two groups (P>0.05). After six-week Tai Chi training, the performance of one leg standing with eyes closed test in Tai Chi group was significantly better than those in control group (11.4±5.5 vs. 4.6±1.58 second, P<0.05) as well as the static balance (224.8±112.3 vs. 482.7±91.1, P<0.05). Moreover, the lower static balance score showed the higher performance they achieved. However, the performance of dynamic balance test between Tai Chi group and control group did not reach significant difference (1525.7±336.3 vs. 1750±321.1, P>0.05).
Conclusions: The data suggest that Tai Chi exercise influence children's balance ability in different levels. For example, Tai Chi exercise improve one leg standing with eye closed and static balance but show no change in the dynamic balance after six-week Tai Chi training. Training duration and baseline balance ability might be the possible reasoned for unchanged dynamic balance. In generally, these results provide that Tai Chi is an effective exercise for improving balance ability in children.

MP-26

Treadmill walking – is it different from walking overground?

M.K. Aaslund and R. Moe-Nilssen

Section of Physiotherapy Science, Faculty of Medicine, University of Bergen, Bergen, Norway

Introduction: Treadmill therapy has become an increasingly popular intervention, and is looked at as being a task-specific intervention for relearning how to walk. The objective of this study was to determine how gait variables are affected by walking on a treadmill, wearing a harness, and using body weight support systems.
Methods: 28 healthy subjects walked during six different walking conditions; overground walking with and without harness, treadmill walking with and without harness, and walking on the treadmill with approximately 30 per cent dynamic and static body weight support. A triaxial accelerometer was used to measure acceleration around the lower back. From this acceleration RMS, tilt of trunk, and cadence was reported. Interstride trunk acceleration variability was calculated by an autocorrelation procedure. All gait variables were compared at a velocity of 1.2 m/s.
Results: General Linear Model repeated measures mixed between-within subject analyses of variance revealed that on the treadmill cadence increased, the trunk tilted more forwards, vertical acceleration RMS increased, and anteroposterior trunk acceleration became more variable. Wearing a harness resulted in more restricted vertical acceleration RMS. When using body weight support acceleration RMS became more restricted in all directions. Interstride trunk acceleration variability increased in anteroposterior and vertical direction, and decreased in the mediolateral direction. Static body weight support tended to give more significant differences compared to dynamic body weight support.
Conclusions: Gait is affected significantly when walking on a treadmill, when using a harness, and when using approximately 30 per cent dynamic and static body weight support. Based on this the task-specificity of treadmill therapy is questioned.

MP-27

Mechanisms of response to locomotor training post-stroke: systematic assessment of motor pattern restitution

M.G. Bowden[1], A.L. Behrman[1] and S.A. Kautz[1]

[1]Brain Rehabilitation Research Center, North Florida/South Georgia Veterans Health System, Gainesville, FL, USA and [2]Department of Physical Therapy, University of Florida, Gainesville, FL, USA

Introduction: Task-specific training such as locomotor training (LT) is based on principles of neuroplasticity and potential neurological recovery, but the effect of training on individual motor control deficits has been poorly studied. We present a systematic, longitudinal approach to differentiate compensatory strategies from motor pattern restitution by examining spatiotemporal and anterior-posterior (A-P) ground reaction force responses to a LT intervention and presenting results from the first group of participants to undergo such an analysis (expected n = 6-8).
Methods: Data from a single participant are presented here: a 45 year-old female with a left-brain hemorrhagic stroke 6 months prior to enrolling in a LT intervention. The program consisted of 36 sessions (3x/week) of LT utilizing both treadmill/body weight support and overground environments. Weekly assessments of spatiotemporals and kinetics were performed by walking over an instrumented walkway (GAITRite) and force-plate instrumented treadmill (Tecmachine). For all kinetic variables, positive and negative values constituted propulsion and braking, respectively. Assessments included: 1) self-selected (SS) walking speeds; 2) step length ratio (SLR), the paretic step length divided by the non-paretic step length; 3) paretic propulsion (Pp), the percentage of propulsion performed by the paretic leg; 4) the summed total of the propulsive and braking impulses (time inte-

gral of A-P forces) generated in paretic pre-swing (PPS), the double limb support prior to the paretic step; and 5) the percentage of the gait cycle where the peak propulsive force occurred.
Results: The participant improved in SS walking speeds (0.65 to 0.83 m/s), and improvements were associated with normalized values for SLR (1.53 to 1.22: normal~1.0) and Pp (13.18% to 29.41%: normal~50%). Improvements in Pp were largely due to improved total impulse in PPS (-2.14 to 8.70 Ns): initial negative values indicate breaking during a phase typically associated with propulsion. This normalization is also reflected by the peak A-P force occurring in portions of the gait cycle normally associated with propulsion and power generation (from 27.22% of the gait cycle to 45.25%).
Conclusions: The above results are consistent with changes that are not purely attributable to compensatory responses and demonstrate longitudinal alterations in the motor control pattern. This approach demonstrates the ability to assess ongoing mechanistic changes to determine effects of therapeutic interventions. This project is funded by VA RR&D Grant B3983-R.

MP-28

Spatio-temporal gait changes during a test of functional capacity after stroke

K.M. Sibley[1], K.K. Patterson[2], A. Tang[1], D. Brooks[3] and W.E. McIlroy[4]

[1]Institute of Medical Science, University of Toronto, Toronto, ON, Canada, [2]Graduate Department of Rehabilitation Science, University of Toronto, Toronto, ON, Canada, [3]Department of Physical Therapy, University of Toronto, Toronto, ON, Canada and [4]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: Sensorimotor dyscontrol combined with increased susceptibility to fatigue after stroke may be exacerbated during functional activities. The purpose of this study was to examine changes in spatial and temporal gait parameters over the course of an extended bout of walking activity.
Methods: Nine stroke patients (8 chronic and 1 sub-acute) performed the Six-Minute Walk Test (6MWT) along a 30 m course. Primary outcomes were velocity and temporal symmetry assessed over the middle 10 m of the course using a pressure-sensitive mat. Case studies also examined individual changes in sensorimotor control.
Results: Preliminary analysis did not indicate any significant group average effects of time over the course of the 6MWT ($p>0.05$), however, there was a large degree of individual variation across subjects. The individual who walked the shortest distance demonstrated a decline in speed and a marked increase in asymmetry, while two patterns emerged among the remaining participants. Four participants maintained steady speed and symmetry, while another four participants demonstrated variable increases and decreases in speed throughout the 6MWT.
Conclusions: Ongoing work is underway with a larger sample size to evaluate for group changes over time. Initial findings suggest that extended effortful activity differentially impacts sensorimotor control of gait after stroke, and may be particularly detrimental for individuals with poorer walking ability. This work highlights the importance of addressing fatigue-related influences on functional activities and provides rationale for focusing on both peripheral and central deficits after stroke.

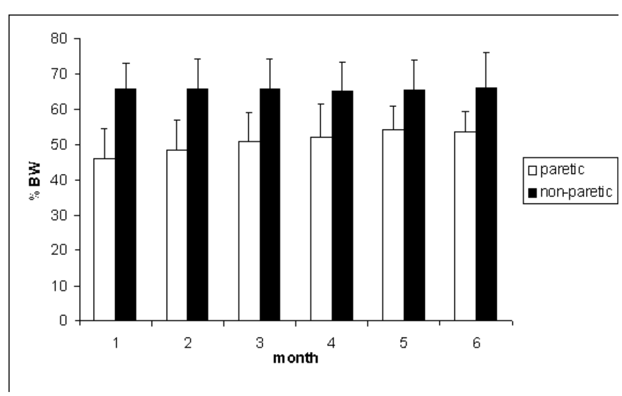
MP-29

Paretic lower extremity loading during sit-to-stand from 1 to 6 months post stroke

S. Manorangsan and V. Mercer

Center for Human Movement Science, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

Introduction: Sit-to-stand (STS) is a critical task for independence in activities of daily living. Many persons recovering from stroke have difficulty bearing weight through, or "loading" the paretic (P) leg, and consequently demonstrate asymmetrical weight bearing during STS. The purpose of this study was to examine P limb loading during STS and its association with gait speed from 1 to 6 months post stroke.
Methods: Subjects were 17 adults (mean age = 56.8±14.2 years) with unilateral non-cerebellar stroke and a Fugl-Meyer lower extremity motor scale score ≤28. Subjects were tested one time per month from 1 to 6 months post stroke. Tests included the 10-m walk performed at self-selected and fast speeds and STS. During STS, a dual force platform system was used to measure P and non-paretic (NP) limb loading, defined as peak vertical ground reaction force (GRF) beneath the limb. Loading of each limb was expressed as a percentage of body weight (%BW), and the ratio of P to NP loading (P/NP) was calculated. Changes in limb loading over time were assessed using repeated measures one-way ANOVA, and relationships between loading and gait speed were assessed using Pearson correlation coefficients (r), all at $\alpha=0.05$.
Results: Mean P limb loading during STS increased significantly over time, while NP limb loading was unchanged (see Figure). Mean P/NP ratio improved from 0.72 to 0.84. Mean self-selected gait speed increased from 0.58 m/s to 0.97 m/s. P limb loading during STS was significantly correlated with gait speed at every time point from 2 to 6 months post stroke (r=0.45-0.50 for self-selected; r=0.35-0.38 for fast) and increased over time. Correlations between NP limb loading during STS and gait speed were negative, were strongest at 1 month post stroke, and decreased over time.
Conclusions: Results of this study support the importance of P limb loading for functional task performance in stroke survivors. Low values for loading of the P limb and high values for loading of the NP limb are associated with slower gait speeds. Increasing P limb loading during functional tasks is an appropriate focus of stroke rehabilitation.



Mean peak vertical GRF during STS

MP-30

Gait characteristics in progressive supranuclear palsy before and after a therapeutic intervention

C. Zampieri and R.P. Di Fabio

Physical Medicine and Rehabilitation, University of Minnesota, Minneapolis, MN, USA

Introduction: Gaze control plays an important role in locomotion. Although vertical gaze palsy and gait instability are cardinal features of Progressive Supranuclear Palsy (PSP), little research has been done addressing oculomotor and gait rehabilitation for PSP. The purpose of the present study was to determine if a balance training program complemented with oculomotor control and visual awareness training was better in improving gait than balance training alone.
Methods: Nineteen patients with PSP participated in this study. All patients were moderately affected by the disease. A group of 10 patients received balance training combined with eye movement training, and a group of 9 patients received balance training only. Patients were assessed before and after treatment on clinical and kinematic gait parameters. Clinical parameters included the Timed Up and Go test (TUG) and eight-foot walking test. Kinematic gait parameters included stance duration, swing time and stride length. A matched pairs t-test was performed for each group separately to compare within group pretest to posttest scores.
Results: Patients who received balance and eye movement training significantly decreased stance duration (pretest=0.93 sec, posttest=0.79 sec, p=0.01) and increased walking speed (pretest=61.53 cm/sec, posttest=72.39 cm/sec, p=0.01). In addition, stride length and TUG improved to values approaching significance (stride length pretest=58.25 cm, posttest=61.86 cm, p=0.08, and TUG pretest=24.32 sec, posttest=20.42 sec, p=0.08). Patients who received balance training alone, only improved stride length significantly (pretest=61.85 cm, posttest=68.56 cm, p=0.01). No significant improvements were observed in terms of swing time for either group.
Conclusions: Our results support the use of eye movement exercise as complementary therapy to balance training to improve gait in patients with moderate PSP. We speculate that plasticity of the Pedunculopontine Nucleus and Frontal Lobe areas may play a role in the improvement of gait in patients who received balance intervention combined with eye movement training.

MP-31

Individuals with chronic low back pain demonstrate temporal alterations and increased lateral motion in sit-to-stand movements performed at different speeds: A Pilot Study

S.L. Jones[1], S.M. Henry[1], J.R. Hitt[1] and A.L. Trombley[1]

[1]Rehabilitation and Movement Science, University of Vermont, Burlington, VT, USA and [2]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada

Introduction: Abnormal movement patterns have been demonstrated by individuals with chronic low back pain (LBP). Individuals with LBP demonstrate altered preferred movement speeds in walking (Lamoth et al., 2006; Al-OBaidi et al., 2003) and sit-to-stand (STS) movements (Coghlin & McFadyen, 1994). These individuals may be able to attain movement speeds equal to healthy controls (Lamoth et al., 2006) but it is not clear whether the movements performed are comparable with respect to balance control. Therefore, the purpose of this study was to compare STS movements performed at different speeds between individuals with and without LBP.
Methods: Five individuals with no history of LBP (NLBP) and 9 individuals with chronic LBP were tested during a standardized STS task. Subjects sat with arms crossed and trunk unsupported on a height-adjusted seat and performed STS movements at three self-selected speeds: fast, slow and preferred. 3-D passive marker coordinates were captured by 3 infrared cameras (50Hz) and kinetic data were recorded at the seat and feet using two forceplates (1000Hz). Temporal and spatial parameters of the centers of mass and pressure (COP) and joint angular kinematics were compared using a 1-way repeated measures ANOVA (velocity), while onsets of joint motion were compared using a 2-way repeated measures ANOVA (velocity*joint); pain group was the grouping factor in both models.
Results: Movement duration did not differ between groups but the proportion of time spent in the acceleration and deceleration phases was reduced and increased, respectively (p=0.006, p=0.078), in subjects with LBP compared to those without. Subjects with LBP demonstrated onsets of joint motion that were more coincident in time than those of the NLBP group, although the sequence of onsets was preserved (p=0.027). Subjects with LBP demonstrated an earlier seatoff that tended to occur closer to the time of peak horizontal momentum in the fast and slow conditions. A trend towards reduced trunk flexion at preferred and slow speeds by subjects with LBP (p=0.075) was the only spatial difference between groups, although subjects with LBP demonstrated earlier peaks of hip (p=0.002) and ankle (p=0.084) flexion. Lateral movement of the COP was increased in subjects with LBP relative to those without (p=0.034).
Conclusions: Individuals with LBP initiated movement more coincidently among joints, resulting in a shorter phase of horizontal acceleration and seatoff that occurred closer to the peak of horizontal momentum. This movement strategy reflects altered coordination in the transfer of horizontal to vertical momentum from the smoothly coordinated transfer demonstrated by the NLBP group to a more sequential pattern. This strategy may be an attempt to achieve greater stability in completing the movement by prioritizing the deceleration phase (Coghlin & McFadyen, 1994). The increased time spent decelerating may also result in increased lateral sway that may reduce the lateral stability of the STS movement.

MP-32

Decreased forces responses in people with chronic, recurrent low back pain

J.R. Hitt[1], S.M. Henry[1], S.L. Jones[1] and J.Y. Bunn[2]

[1]Department of Rehabilatation and Movement Science, University of Vermont, Burlington, VT, USA and [2]Department of Mathematices and Statistics, University of Vermont, Burlington, VT, USA

Introduction: Abnormal movement strategies due to differences in neuromuscular control have been associated with low back pain (LBP). This study characterized the surface force production in response to multi-directional support surface translations in subjects with and without chronic, recurrent LBP.

Methods: 26 subjects with chronic, recurrent LBP of longer than 6 months (# female = 16; 39(13) yrs) and 24 subjects without LBP (NLBP) (# females = 12; 33(11) yrs) were recruited from the community. Subjects with LBP were tested while not in a flare-up of their LBP. Subjects were randomly presented with support surface translations in 12 different horizontal directions, 3 trials in each of the 12 directions. Subjects were asked to assume their natural self-selected stance width and toe out angle with each foot placed on a separate forceplate. The horizontal forces (Fx, Fy) were vectorially summed to produce a resultant horizontal plane force vector under each foot over multiple time intervals post surface translation onset: active phases A (100 - 400 ms) and B (200 - 400ms) as well as seven, 75 ms time epochs from 25 - 550 ms. The resultant forces in the different time intervals were analyzed with a repeated measures ANOVA designed to characterize the force responses in the 2 groups. A p – value of 0.05 or less was used to determine significance.

Results: The LBP group was not significantly different from NLBP group with regard to height, age, or body mass index ($p > 0.1$). Subjects with LBP differed from NLBP on measures of pain for the McGill Pain Questionnaire and the numeric pain index ($p < 0.01$). For both groups the horizontal force vector responses were modulated across all translation directions in each of the time intervals and epochs calculated ($p < 0.01$). Additionally, subjects with LBP exhibited decreased horizontal force vector magnitudes across all directions for active periods A and B ($p < 0.05$) for both the right (R) and left (L) foot as well as in the individual time epoch 400 - 475 ms (R: $p = 0.06$; L: $p = 0.02$) compared to NLBP subjects.

Conclusions: Reduced horizontal force responses following support surface translations reflect that the automatic postural responses of subjects with LBP are altered. The decreased horizontal force vector magnitudes observed in the LBP group suggests that these subjects are adopting an overall stiffening strategy that limits the magnitude of their surface force responses. Previously we reported that subjects with LBP demonstrated reduced joint torque magnitudes and later torque peaks compared to healthy controls (Jones et al., 2005), also suggesting the adaptation of a stiffening strategy. A stiffening strategy could limit the amplitude of the body movement over the base of support and may result in decreased support surface force magnitudes.

MP-33

Differentiating EMG Patterns in Subjects With and Without Chronic, Recurrent Low Back Pain

S. Henry[1], C.L. Beardsley[1], J.R. Hitt[1], S.L. Jones[1] and M.G. Gardner-Morse[2]

[1]Department Rehabilitation and Movement Sciences, University of Vermont, Burlington, VT, USA and [2]Department of Orthopaedics & Rehabilitation, University of Vermont, Burlington, VT, USA

Introduction: Temporal and spatial activation patterns in electromyography (EMG) recorded from multiple muscles may elucidate differences in neuromuscular control strategies among subject groups. However, such a protocol generates large, complex datasets whose interpretation is not self-evident. Multivariate techniques, such as principal components analysis (PCA), can help distill complex relationships without presumptive a priori biases and help to characterize underlying motor control impairments. The purpose was to quantify EMG patterns using PCA to determine if subjects with low back pain (LBP) exhibit diminished dimensionality (minimum number of components needed to adequately represent the measured EMG) compared to controls.

Methods: Subjects with (n=12) and without (n=10) chronic LBP were presented with support surface translations in 12 different horizontal directions (3 trials per direction randomly presented). EMG data from 10 trunk and 2 leg muscles were full-wave rectified and then low-pass filtered. To capture automatic postural responses (APR), the analysis window was from the onset of platform motion to 500ms. This window was time-normalized to 100% and the amplitude of each muscle was normalized to the maximum EMG activity for the window of interest. The Karhunen-Lóeve expansion was used to compute principal components. Via separate analysis of each group, the dimensionality of the data from LBP subjects was compared to the dimensionality of data from control subjects. Then PCA was repeated for the combined data. The mean square error (MSE) reflected how well the EMG response fit the principal components. MSE was compared using a univariate ANOVA with muscle, group, pre/post treatment status, and translation direction as fixed factors. Tukey's test was used for post hoc comparisons.

Results: sgffdsgsWith all data included, subsets of data arose based on significant differences in how well the global patterns fit (MSE). These distinctions in MSE partitioned ventral versus dorsal muscle responses, and further separated data into forward versus backward/lateral translations. The LBP group had equivalent or lower dimensionality in all translation directions/muscle combinations ($p<0.02$). For forward translations, LBP subjects were different from controls via MSE for the internal obliques bilaterally, right external oblique, and right rectus abdominus ($p < 0.006$).

Conclusions: Lowered dimensionality can reflect impairment and possibly "reflects the loss of control of variables related to the minimization of movement variability" (Longstaff, 2003). Loss of movement variability/speed has been found with LBP (Marras et al 1986; Henry et al, 2006). PCA was useful for extracting modes common to all EMG patterns recorded during APRs. By first identifying the patterns common across all subjects, we can then quantify differences in subjects with and without LBP. Identifiable deviations from the fundamental cadre of patterns may in turn help to direct rehabilitation.

MP-34

Individuals with low back pain modulate their muscle activity with different tasks

A.L. Trombley[1], S.M. Henry[1], J.R. Hitt[1], S.L. Jones[1] and J.Y. Bunn[2]

[1]Dept of Rehabilitation and Movement Science, University of Vermont, Burlington, VT, USA and [2]Department of Mathematices and Statistics, University of Vermont, Burlington, VT, USA

Introduction: Low back pain (LBP) is associated with motor control impairments (Sahrmann 2002, O'Sullivan 1997); characterizing such impairments can help to guide rehabilitation.

The aim of this study was to examine abdominal muscle activation during 4 activities commonly used clinically to recruit these muscles.

Methods: Surface electromyography (EMG) data were collected from 6 control subjects without LBP (CON) and 12 subjects with chronic, recurrent LBP while they performed 4 tasks: the abdominal curl, double leg raise (DLR), and left and right trunk twists in sitting. Subjects with LBP were randomly assigned to 1 of 2 treatment groups, segmental stabilization (SEG; n = 6) and general strength/conditioning training (SCG; n = 6) and each group received 10 treatments. EMG data were collected initially and 10 weeks later from the rectus abdominus (RA) and the internal (IO) and external oblique (EO) muscles bilaterally for 5 s. The RMS was calculated for the 2.5-4 s time interval. Ratios were calculated for EO/RA and IO/RA activity, using data normalized to each subject's individual muscle's maximal activity for each testing session.

Results: In general, at initial testing, the LBP group activated their left (L) IO ($p<0.01$) across 3 of 4 tasks to a greater percentage of their maximum than did the CON group, whereas right (R) IO showed increased activation for the R trunk twist only ($p<0.01$). This is true for R RA also ($p<0.04$); however there were no group differences for the EO muscles ($p>0.28$). There was modulation of IO ($p<0.03$) and RA ($p<0.01$) activity but not for EO ($0.16< p<0.22$) across the 4 tasks for CON and LBP groups. However, activation of the L IO muscle during the L twist ($p=0.04$) and trunk curl ($p=0.05$) was greater than for the DLR in the LBP group. The L twist also resulted in greater L IO activity than the R twist ($p<.01$). Similarly, the R IO muscle activity was greater during the R twist compared to the DLR ($p=0.04$) and the L twist ($p<0.01$). The trunk curl elicited greater activation of the RA bilaterally compared to the DLR task ($p\leq0.01$). The LBP group had neither pre-post treatment effects ($0.15< p< 0.80$) nor differences due to treatment type ($0.19< p<0.61$). In the SEG group, there was a non-significant trend for the ratio of IO/RA for the DLR task to increase post-treatment.

Conclusions: LBP patients were able to modulate their muscle activity with different tasks, although initially appeared to activate their muscles at a higher percent of their maximum voluntary contraction than those without LBP. When prescribing specific exercises to patients with LBP, the trunk curl is particularly good at recruiting the RA, but does not allow for differential abdominal muscle activation. Exercises that incorporate twisting appear to recruit the deeper ipsilateral muscles in a more specific pattern. No pre-post treatment effects were seen in this study likely due to insufficient statistical power.

MP-35

Relation between weight-bearing asymmetry and functional performance after stroke

A. Leroux, C. Hovington and H. Pinet

Exercise Science, Concordia University and Centre de Recherche Interdisciplinaire en Réadaptation du Montréal Métropolitain - Constance-Lethbridge Rehabilitation Center, Montréal, QC, Canada

Introduction: Hemiparesis is a common stroke-related impairment characterized by decreased muscle strength in the affected lower limb and by a shift of the body weight toward the unaffected side creating an asymmetrical pattern of weight-bearing in upright posture. The purpose of this study was to investigate the relation between weight-bearing asymmetry and functional performance in hemiparetic subjects secondary to stroke.

Methods: Seventeen hemiparetic subjects took part in this study. A weight-bearing asymmetry index was established for double-legged stance and sit-to-stand tasks using the difference in vertical ground reaction forces (expressed as a percentage of body weight) between the non-paretic and the paretic leg. Functional performance was measured using the Timed Up-and-Go (TUG), Berg Balance Scale (BBS), 6-Minute Walk Test (6-MWT) and the lower-extremity component of the Chedoke-McMaster Stroke Assessment (C-MSA). The relation between weight-bearing asymmetry and functional performance measures was assessed with the Spearman correlation coefficients (ordinal data: BBS and C-MSA) and the Pearson product-moment correlations (continuous data: TUG and 6-MWT).

Results: Hemiparetic subjects showed an asymmetry index of 20.6% and 38.8% for double-legged stance and sit-to-stand tasks, respectively. The asymmetry index for double-legged stance was significantly ($p< 0.05$) related to the TUG, BBS, 6-MWT and C-MSA with r values of 0.76, -0.52, -0.67 and -0.63, respectively. Similarly, the asymmetry index for sit-to-stand was significantly ($p< 0.05$) related to the TUG, BBS, 6-MWT and C-MSA with r values of 0.66, -0.56, -0.70 and -0.58, respectively.

Conclusions: Results revealed that the weight-bearing asymmetry measured during static (double-legged stance) and dynamic (sit-to-stand) tasks was significantly related to functional performance measures in hemiparetic subjects. Furthermore, for both static and dynamic tasks, weight-bearing asymmetry showed stronger correlations with mobility (TUG) and walking performance (6-MWT) measures than with balance (BBS) and lower-extremity impairment (C-MSA) measures. These results show the importance of addressing weight-bearing asymmetry in stroke rehabilitation since this impacts the functional performance level of hemiparetic subjects, particularly in walking and mobility functions.

MP-36

Postural strategies emerging in complete paraplegic patients verticalized with functional electrical stimulation

C. Simon[1], D. Delignères[2], D. Guiraud[1], C. Fattal[3] and C. Azevedo Coste[1]

[1]DEMAR, INRIA/LIRMM, Montpellier, France, [2]EDM, Sport Science University, Montpellier, France and [3]Propara, Propara Neurological Center, Montpellier, France

Introduction: Functional electrical stimulation (FES) allows for performing standing in complete paraplegic patients. Benefits of an active verticalization are both psychological and physiological. FES creates a split-body situation where the body is in part controlled externally, whereas the rest of the body remains under the voluntary influence of the central nervous system. Nevertheless, the patient has an indirect action on his lower body through the closed mechanical chain going from hand supports to feet. This study aims at understanding the coordination patterns between upper and lower body in order to ensure postural

balance. In valid subjects, regardless of disturbances, 2 stable postural patterns seem to emerge : a phase mode where hips and ankles' angles go in a same direction and an anti-phase mode where hips and ankles' angles go in opposite directions.
Methods: Patients suffering from complete spinal cord lesion were equipped with surface electrodes delivering electrical stimulation to 4 muscular groups in each leg, ensuring that 1) lateral movements of pelvis were stabilized; 2) knee were locked; 3) ankle were free to rotate. The stimulation sequences were parameterized offline and pre-programmed for each patient. The protocol was to stand in between parallel bars and maintain postural balance by aligning head, pelvis and ankles. In order to help patients in adopting the correct posture, a visual feedback assistance was provided ; a screen was set up in front of the patients where they could see their own profile. A video motion analysis system recorded the positions of 16 passive markers. 6-degree of freedom force sensors where fixed on the handles to record upper limbs' efforts on the parallel bars. Insoles were placed inside the patient's shoes to record pressure distribution. Patients were trained to FES technique in a lying position during the 1st week followed by 2 days of rest. The 1st day after this conditioning, they were familiarized with the verticalization protocol. We started recording data from the 2nd day on. 5 try-outs of 1mn-standing were performed by each patient.
Results: The data analysis focused on windowed crosscorrelations between absolute angles, of upper and lower limbs. The observed coordination modes were evaluated through their occurring frequency and efficiency. Efficiency was estimated based on the normalized efforts applied by the patients on the handles. The more the patients were supporting their weight on their arms the lesser efficient was the posture. Despite the patient group being heterogeneous (lesion level and time since injury) and despite the significantly different efforts they applied on the handles, it seems that the anti-phase mode is the most frequently used by the patients, and also the most efficient. Nevertheless, this mode remains unstable as it is not maintained over the trials.
Conclusions: Stabilizing the anti-phase mode by training should improve efficiency of vertical posture and increase the functionality of standing.

MP-37

Improving stroke patient gait using robotics and model-based FES

D.L. Benoit[1], V. Krishnamoorthy[2], S. Banala[2], W. Hsu[2], R. Perumal[2], T. Kesar[2], J.P. Scholz[2], S.K. Agrawal[2], S. Binder-MacLeod[2] and T.S. Buchanan[2]

[1]School of Rehabilitation Sciences, University of Ottawa, Ottawa, ON, Canada and [2]Center for Biomedical Engineering Research, University of Delaware, Newark, DE, USA

Introduction: Post-stroke hemiparesis often results in abnormal gait patterns and reduced mobility. The goal of this project is to develop an intervention protocol which combines gravity-balanced robotic assistance device (GBO), muscle modeling and functional electrical stimulation (FES) to improve gait function in a hemiparetic population.
Methods: The GBO provides adjustable degrees of assistance during the gait cycle by compensating for the effect of gravity on the subject's affected lower-limb(Fig.1). Intermittent real-time visual feedback based on limb position was provided to the subject and they altered their motion pattern towards a desired profile based on healthy controls. The level of assistance from the GBO was progressively reduced throughout the five weeks of training (15 sessions of 40 minutes). In addition, FES was used to supplement the volitional muscle activation patterns of the ankle plantar- and dorsi-flexors. The stimulation level was determined through muscle modeling and simulation in order to minimize the required activation level. Stimulation used constant and variable frequency trains to minimize muscle fatigue and optimize force development.
Results: To date, one subject (male 58yr; 3.5yr post-stroke; right-side hemiparesis) has been trained resulting in increased in knee and hip joint excursions during gait, muscle force generating ability and unassisted self-selected walking speed. However improvement reduces with diminishing levels gravity assistance, indicating a longer training period may be required to facilitate physiological changes.
Conclusions: Improvements in gait indicating patient plasticity and adaptation from the training were evidenced after 15 sessions and further patient training is underway.

Fig. 1: The patient in the GBO during treadmill walking.

MP-38

Laterality responses during Anticipatory Postural Adjustments in Transversus Abdominis: a repeatability study

G.T. Allison[1], S.L. Morris[2], B. Lay[2] and S.M. Henry[3]

[1]School of Surgery and Pathology, The University of Western Australia, Perth, WA, Australia, [2]Human Movement and Exercise Science, The University of Western Australia, Nedlands, WA, Australia and [3]Department of Physical Therapy, University of Vermont, Burlington, VT, USA

Introduction: The deep trunk muscles are considered to have different postural control mechanisms when compared to the more superficial muscles. The transversus abdominis (TA) muscle is thought to be under feedforward (FF) control and is activated in a non directionally specific manner in normal subjects when they raise their arm(s) suddenly in different planes. The assumption that these deep trunk muscles, especially the TA, are acting bilaterally and symmetrically in a FF manner during rapid arm raising has limited supporting evidence.

Methods: This study utilised a self paced rapid arm raising protocol in normal healthy control subjects. The first part of the study utilised a case study of three repeated assessments of the TA muscle bilaterally using fine wire EMG signal recordings over a 7 year period. The EMG signal linear envelopes were compared between testing sessions. In a subsequent study, surface EMG of the biceps femoris, external oblique and anterolateral abdominal muscles were recorded bilaterally. For both studies the FF window was defined at 50ms after the onset of anterior deltoid (AD).

Results: The repeated assessment of the TA muscle over 7 years showed a high degree of consistency during the FF window. There was clearly a laterality response in the deep abdominal muscles during right arm raising. The contralateral (left) TA muscle was activated prior to the AD and the ipsilateral (right) TA muscles. This laterality response was reversed when the left arm was rapidly raised. These findings are consistent with recent data (n=7) [Morris et al] that show the contralateral TA and internal oblique muscles generate a FF response and the ipsilateral muscles a later response.

Conclusions: These findings suggest the TA muscle is directionally specific in normal subjects and refutes the current generalisation associated from flexion and extension arm raising studies. During rapid arm raising, there is an asynchronous activation pattern of the deep abdominal muscles which is consistent with the notion that the muscles are contributing to an angular momentum associated with the focal task of rapidly raising the arm. Thus, bilateral synchronised co-activation of the TA muscle prior to the activation of the AD muscle is NOT the normal motor control pattern. These findings have critical implications on the interpretation of the role of the deep trunk muscles in spinal stability during ballistic motor patterns and refute the assumptions underlying some core stability training programs in athletes.

MP-39

Effects of whole body vibration training in chronic stroke patients: A randomized controlled pilot study

S.M. Verschueren, A. Bogaerts and H. Feys

Department of Rehabilitation Sciences, Katholieke Universiteit Leuven, Leuven, Vlaams-Brabant, Belgium

Introduction: Whole body vibration (WBV) training is recently being promoted as an efficient alternative for strength training in healthy young and elderly adults (1,2), whereby the muscle contractions are evoked by the tonic vibration reflex. Due to the reflexive muscle contractions and the powerful somatosensory stimulation provoked by the vibratory stimulus, WBV-training might be particularly useful for stroke patients. The aim of this randomized controlled pilot study was to assess the effect of 6 weeks WBV-training in chronic stroke patients.

Methods: Fourteen chronic stroke patients were randomly assigned to the WBV-group (n=7) or a control (CON) group (n=7). The WBV-group performed knee-extensor exercises on a vibration platform (Powerplate) 3 times/week for 6 weeks. The CON-group did not participate in any training. Muscle strength of quadriceps was measured using an isokinetic dynamometer (Biodex system 3 pro). Postural control was assessed by means of the Equitest system (Neurocom International Inc.). Muscle tone was evaluated with the Ashworth scale. Data were sampled at baseline, at 6 weeks, and at 12 weeks (follow-up). Data were analyzed by means of repeated measures ANOVA.

Results: The results show that 6 weeks of WBV training resulted for the hemiplegic leg in a significant increase in isometric strength (+16%, at knee joint angle of 60°), and a significant increase in isokinetic strength (+19%, velocity of 240°/s). These improvements in strength were maintained during the 6 weeks follow-up period. No effects were found for the non-hemiplegic leg. Muscle tone did not change significantly following WBV, if anything it tended to decline. No changes in postural control were measured following 6 weeks of training. No adverse effects of vibration were noted.

Conclusions: These preliminary results suggest that WBV may a safe and feasible way to increase lower limb muscle strength in chronic stroke patients. Further research is needed to assess the long-term (functional) effects of WBV in a larger sample and to optimize training protocols.

MP-40

Intensive walking and exercise therapy during early acute stage of stroke

S.H. Peurala[1], O. Airaksinen[3], P. Jäkälä[2], I.M. Tarkka[4] and J. Sivenius[4]

[1]Finnish centre for interdisciplinary gerontology, University of Jyväskylä, Jyväskylä, Finland, [2]Department of Neurology, Kuopio University Hospital, Kuopio, Finland, [3]Department of Physical Medicine and Rehabilitation, Kuopio University Hospital, Kuopio, Finland and [4]Brain Research and Rehabilitation Center Neuron, Kuopio, Finland

Introduction: Nowadays, mobilization of patients with cerebrovascular stroke is provided right after the stroke onset. However, the intensive exercise therapy is usually begun only about ten days after the stroke onset. In the present study, the intensive gait-oriented physiotherapy was provided as early as possible, often in just few days, after the onset of stroke.

Methods: The randomized controlled study was performed in an acute care hospital. 37 patients (8 ± 3 days post-stroke) completed the three weeks' rehabilitation period. At start, 26 patients were unable to walk or needed two assistants to walk, 9 patients needed one assistant, and 2 patients needed to have someone walking beside them to give them confidence. Patients were randomly assigned to two groups: 1) body-weight supported electromechanical gait trainer exercise (GT, n=22), and 2) walking on the floor (WALK, n=21). Patients practised up to 60 minutes to achieve 20 minutes' real walking time in a session. Each patient received also additional physiotherapy 55 minutes daily. The efficacy of rehabilitation program was assessed in 10 meters' walking time test, 20 meters' walking time test, six minutes' walking distance test, Modified Motor Assessment Scale, Rivermead Motor Assessment subscales of gross motor function and leg & trunk, and Rivermead Mobility Index. The patients evaluated their effort according to the Borg rating of perceived exertion scale.

Results: The mean walking distance was 8 500 ± 1 700 meters in the GT group and 10 400 ± 5 700 meters n the WALK group (group difference NS). Mean perceived exertion during the walking exercises was 14.5 ± 1 on the Borg Scale. All walking tests and scores in motor scales improved ($p<0.0005$) and no differences in improvements were found between groups ($p>0.05$).

Conclusions: Despite a very early stage of stroke, remarkable amount of repetitive task-specific walking exercises could be achieved and yet patients evaluated their effort only slightly strenuous or strenuous. All patients in GT and WALK groups improved their motor performance. The improvement in gait parameters and motor tasks was not related to the type of exercise. Both training methods, the body-weight supported training and traditional walking training, resulted in better gait after intensive three weeks' rehabilitation program, but exercising in the gait trainer demanded less effort from the therapists. In the future, the longitudinal studies will be needed to compare the long –term effects of intensive and conventional treatments as well as the timing of rehabilitation. The effort perceived by therapists should also be studied.

MP-41

The electromyographic activity of lower limb muscles during obstacle avoidance in patients with a trans-tibial amputation

C.J. Hofstad[1], V. Weerdesteyn[2], H. Linde van der[1], B. Nienhuis[1], A.C. Geurts[2] and J. Duysens[1]

[1]Research, Development & Education, Sint Maartenskliniek, Nijmegen, Netherlands and [2]Rehabilitation Medicine, Radboud University Medical Centre, Nijmegen, Netherlands

Introduction: Walking is usually regarded as an activity requiring little or no cognitive effort (Geurts et al., 1991). However, for people with a lower limb amputation walking may present an increased cognitive load since they suffer from absent sensory input from the lower limb. Therefore, the normal system of feedback about position in space is lost, and must be substituted by increased reliance on other sources of information such as cognition and vision (Fernie et al., 1978). When facing perturbations of the ongoing walking pattern, lower limb amputees are expected to rely even more on cognitive sources, because such tasks are probably less automated than normal walking. In a time-critical obstacle avoidance task, people with trans-tibial amputation are known to be less successful than healthy adults (Hofstad et al., 2006). This may be due to delayed reactions because of increased central processing time. Alternatively, reduced muscle strength could also explain the reduced success. In the present study we examined whether people with a trans-tibial amputation have delayed reactions (indicative of increased cognitive involvement) and/or reduced response amplitudes (indicative of reduced strength) than controls when faced with a suddenly appearing obstacle.

Methods: Nine patients with a trans-tibial amputation and 14 healthy controls participated in this study. Subjects walked on a treadmill at 2 km/h. In 2 series of 12 trials each, an obstacle was dropped in front of the prosthetic leg (P-leg) or the non-prosthetic leg (NP-leg) of the amputation group and the left leg of the control group. The obstacle was dropped in late stance, early swing or mid-swing. Surface EMG activity of the biceps femoris (BF), rectus femoris (RF), tibialis anterior (TA) and medial head of the gastrocnemius (GM) was recorded. From the P-leg only EMG-activity of the BF and RF was recorded.

Results: For each muscle recorded, the onset latencies of the people with a trans-tibial amputation were delayed compared to the control group. For example, onset latencies for the BF of the avoiding leg was 118.3ms ± 1.8 (mean ± SE) in the control group versus 139.6ms ± 3.9 and 140.9ms ± 3.1 in the P-leg and NP-leg, respectively. The differences were largest for the mid-swing condition (yielding the highest time pressure) (107.8ms ± 2.8 in the control group versus 148.3ms ± 7.5 and 137.2ms ± 7.8 for the P-leg and NP-leg, respectively). As compared to controls, the response amplitudes (measured over the first 100 ms of the response after obstacle release) in the upper leg muscles was, on average 29% and 32% smaller in the P-leg and NP-leg, respectively.

Conclusions: The delayed onset latencies suggest that obstacle avoidance reactions in trans-tibial amputees are more cognitively controlled than in healthy people. The smaller response amplitudes are indicative of reduced muscle strength. Both factors are expected to play a role in the reduced success of trans-tibial amputees in obstacle avoidance under time pressure.

MP-42

Effectiveness of visual feedback training for improving static balance in the elderly depends on the direction of visually induced weight shifting

V. Hatzitaki[1], S. Spiliopoulou[2], T. Nikodelis[3] and I.G. Amiridis[2]

[1]Laboratory of Motor Control and Learning, Aristotle University, Thessaloniki, Greece, [2]Laboratory of Neuromuscular Control and Therapeutic Exercise, Aristotle University at Serres, Thessaloniki, Greece and [3]Biomechanics Laboratory, Aristotle University, Thessaloniki, Greece

Introduction: Side by side Weight Shifting (WS) controlled by visual feedback is used as a training tool for improving standing balance (Marigold et al., 2005; Sihvonen et al.,2004). Although this training seems to improve the efficacy of the hip load/unload mechanism, little is known regarding training-induced adaptations of the ankle mechanism as a result of practicing WS in the sagittal plane (heel to toe rocking). The impact of the two direction-specific WS training protocols on reducing postural sway in the sharpened-Romberg stance was tested in fifty one (51) community-dwelling elderly women (70.89±5.67 years, 87.5±9.64 Kg), all free from any neurological and/or musculoskeletal impairment.

Methods: Participants were randomly assigned into one of three groups: a group that practiced WS in the Anterior/Posterior direction (A/P group, n=20), a group that practiced WS in Medio/Lateral direction (M/L group, n=15) and a Control Group (n=16). Participants stood over a dual force platform (ERBE Balance System) that provided on-line visual feedback about each foot's force vector. The aim of the task was to continuously shift body weight between the toes and the heel (for the A/P group) or between sides (for the M/L group) while maintaining each foot's force vector within a visually specified sign waveform constraint. Each training session lasted 25 minutes and was divided into 3 phases: a) Warm-up (5min), b) main phase (15 min, three blocks of five weight-shifting trials separated by one-minute intervals) and c) a recovery phase (5min). Participants of the two training groups performed 12 training sessions (3s/week, 4 weeks). In order to progressively increase difficulty of the task, the level of allowed bodyweight variation in the force applied by each foot progressively decreased from 30% to 10% during the last week of training. Effects of training were quantified during 15s of Tandem standing by recording Center of Pressure (CoP) variations (100 Hz, custom-built force platform, Biomechanics Lab, Auth) and angular segment kinematics (100 Hz, Flock of Birds, Ascension Inc, VT).

Results: A significant group by test interaction for all measured variables confirmed that training effects were direction-specific. Heel to toe WS practice induced a significant reduction of CoP amplitude in the A/P direction ($P<0.01$) in association with a significant decrease of lower leg's pitch rotation and upper trunk's roll rotation ($P<0.01$). On the other hand, non-significant changes in CoP amplitude and segment kinematics were noted for the M/L training group.

Conclusions: These results point to the collaborative contribution of the hip load/unload and ankle motor mechanisms in controlling the tandem stance and stress the importance of expanding WS training protocols in the sagittal direction in order to enhance the contribution of the ankle mechanism in the control of static balance.

MP-43

Effects of mechanical support stimulation on the recovery of poststroke movement disorders and brain activity in healthy subjects

L. Chernikova[1], R. Umarova[1], I. Saenko[2] and I. Kozlovskaya[2]

[1]Institute of Neurology of RAMS, Moscow, Russian Federation and [2]SSC RF Institute of biomedical problems, Russian Academy of Sciences, Moscow, Russian Federation

Introduction: Essentially important trigger role of support deprivation in the development of disturbers of tonic motor system and pose synergies in conditions of microgravitation and prolonged hypokinesia is well known. The mechanical support stimulator (MSS) of feet has been created for preventive maintenance of the support afferentation deficiency. However the role of this device in prevention of the locomotion disturbances at the poststroke patients remains unclear. In this study we tried to assess the influence of mechanical stimulation of supporting feet zones (MS SFZ) on the recovery of the motor disturbances and the terms of verticalization.

Methods: The MSS device imitates the feet afferentation, obtained by natural walking with their physical action on the feet receptors. The pneumoinsoles of the MSS device consisted of the pneumocameras and they were installed in fixing footwear. During MS SFZ there were stimulated the calcaneum and instep support zones of feet at patients and healthy subjects. The distribution and temporary characteristics of the pressure were imitating the natural walking. The mode of slow walking was used (75 steps/min and pressure 0,5±0,15 kgf/cm2 in a pulse regime.19 patients with acute stroke were included in this study. The control group consisted of 9 patients which received only traditional rehabilitation. The basic group consisted of 10 patients which additionally received 10 sessions of MS SFZ (for 20 minutes). Patients were assessed by Copenhagen Stroke Scale, Ashworth Scale, Barthel Index. We have used the functional MRI to assess the afferent input obtained by MS SFZ at 6 healthy subjects. Functional MRI was made in a block-design at 1.5T tomograph (Symphony, Sciemens) with alternation of the feet stimulation (30 sec) and the rest period (30 sec) during 3 min for the left, then the right foot, then for both feet in the treatment regimen imitating walking (MS SFZ).The data were analyzed using SPM5.

Results: The ANOVA analysis have shown that the patients of the basic group received the MS SFZ therapy had a better recovery and the terms of transfer in vertical position than the patients of the control group ($p<0.05$). The functional MRI analysis demonstrated the activation of the contralateral sensorimotor area while the one foot stimulation. The stimulation of both feet (MS SFZ) leaded to bilateral activation of the superior parietal lobes besides the activation of the corresponding sensorimotor cortex. So the walking imitating with MS SFZ obtained another activation pattern than the stimulation of only one foot.

Conclusions: May be for the better recovery of such complex physiological act as walking we need in another approach than just physical exercises. The walking imitating with MS SFZ supply the qualitative another afferentation than just stimulation of one foot, which demonstrates the involvement of the another pathways obtaining better recovery. The study was supported by RFBR 04-04-48989-a and RFH 06-06-00275

MP-44

Locomotor training speed influences lower extremity motor activation in clinically motor complete spinal cord injury

C. Patten[1], J.P. Jaramillo[1], A.P. Grogan[1], J.K. Teraoka[2] and G. Chen[1]

[1]Rehabilitation R&D Center, VA Palo Alto HCS, Palo Alto, CA, USA and [2]Orthopaedic Surgery, Stanford University, Stanford, CA, USA

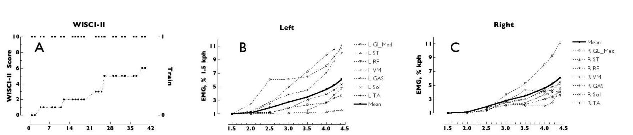
Introduction: Locomotor training holds promise for promoting recovery of walking function in persons with neurologic impairments. Several parameters contribute to the paradigm: body weight support (BWS), treadmill speed and assisted swing phase limb advancement. However, no clear rationale exists for establishing or adjusting these parameters for training. Even in the absence of supraspinal input to the spinal cord, EMG is modulated with increased stepping speed independently of loading. This suggests that effective training involves higher stepping speeds but such speeds are difficult to attain during locomotor training. We investigated the effect of stepping speed on patterned lower extremity motor activity during locomotor training using a Lokomat.

Methods: A 50 year old male, 16 months s/p iatrogenically-induced T10-11 paraplegia (ASIA B) participated in 24 sessions of robotic-assisted locomotor training involving 30 minutes of stepping. The robot was operated using bilateral position control and compliant BWS. Our Lokomat can deliver speeds up to

5.0 kph, corresponding with normal stepping speeds. Mean stepping speed ranged from 2.76(±0.4) kph in Wk 1 to 4.26(±0.03) kph during Wk 6. BWS was held relatively constant between 86.8% (±1.2)–77.8% (±0.4). Once weekly, EMG was collected from 7 leg muscles bilaterally. At Week 4 stepping speed was systematically increased in 8 increments from 1.5–4.4 kph. The rectified integrated linear EMG envelope was calculated, normalized by stride time, averaged (8–10 strides/speed) and expressed relative to EMG at 1.5 kph.

Results: The subject was initially unable to produce volitional leg activity. Following Session 4 volitional stepping (right > left) emerged and continued to improve translating to functional improvements (Fig A). Each week EMG was observed in more muscles with right leg activity preceding left. Modest EMG modulation (0.9–2.5x) was observed between 1.5 and 2.0 kph, corresponding with typical locomotor training speeds (Figs B, C). Above 3.5 kph, EMG modulation was marked, especially in: gluteus medius bilaterally, left vastus medialis and tib. anterior–all muscles in which EMG had been inconsistent and low magnitude. The overall EMG modulation pattern suggests a threshold speed above which afferent inputs produce robust excitatory influences on motor output.

Conclusions: Robotic-assisted locomotor training is not wholly passive. These data suggest a threshold for velocity-dependent inputs that exceeds typical locomotor training. We hypothesize that training at normal stepping speeds contributed to functionally significant improvements in motor activity observed in this individual with clinically motor complete SCI.



MP-45

Symmetry and regularity of gait in transfemoral amputees assessed by autocorrelation of body-fixed, sensor signals

M. Raggi[1], A. Tura[3], L. Rocchi[1], A. Cutti[2], D. Orlandini[2] and L. Chiari[1]

[1]DEIS, Universita' di Bologna, Bologna, Italy, [2]INAIL Prosthesis Centre, Vigorso di Budrio, BO, Italy and [3]Institute of Biomedical Engineering, National Research Council, Padova, Italy

Introduction: The optimal usage of lower-limb prosthesis is a difficult task, often requiring a long training period. An automated wearable system able to monitor the patient's walking patterns and to provide real-time biofeedback in the case of deviations from a specific gold-standard may be of great help for physical therapists. For this reason, we developed a wearable system based on body-fixed-sensors able to quantify the symmetry and regularity of gait.

Methods: Three subjects wearing a lower limb transfemoral prosthesis participated in this study (P1, P2, P3), mean age 37 years. P1 and P2 were wearing the prosthesis for 3 months, P3 for 2 years. Two healthy control subjects (C1, C2), mean age 27 years, served as the control group. Subjects performed plain gait along a 40 m rectilinear path (number of gait sessions: 1 for P1 and P3, 2 for P2, 4 for C1 and C2). Five body-fixed sensors were used (XSENS, NL). They were placed on the thorax at the xiphoid appendix, and the left and right, thigh and shank. The local sensor axes were as best as possible aligned with the sagittal, longitudinal, and mediolateral anatomical-axes. Data were sampled at 100 Hz. In particular, we analyzed the 3-D accelerations (ACC) provided by the system. We computed the unbiased autocorrelation coefficients (Moe-Nilssen et al., J. Biomech, 2004). The coefficient of the first dominant period, Ad1, expresses the regularity of the acceleration between neighbouring steps. The coefficient of the second dominant period, Ad2, expresses the regularity of neighbouring strides. The higher is Ad1 (Ad2), the higher is the degree of regularity of step (stride). The maximum value for Ad1 and Ad2 is 1.

Results: Ad1 computed from thighs and shanks was much lower than Ad1 from the thorax. This can be explained by the asymmetrical position of thigh and shank with respect to the body center of mass. However, even Ad2 was always lower in thighs and shanks than in thorax, suggesting that sensors fixed on the lower limb may underestimate the stride regularity. As regards the different components of ACC, the longitudinal one provided the highest values for both Ad1 and Ad2 in all sensors. The results for the longitudinal ACC of the thorax are reported in Table 1. Both Ad1 and Ad2 were lower on average in the amputees than in the control subjects, but the major differences were seen on Ad1 (t-test: $P<0.0001$).

Conclusions: In agreement with the therapist's observations, these results showed that the amputees have poor symmetry between steps compared to control subjects, thus indicating a non optimal use of the prosthesis. The proposed method seems to be able to quantitatively evaluate the walking performance of subjects wearing lower limb prosthesis.

Table 1 - Coefficients of the dominant peaks of the autocorrelation function

	P1	P2	P3	C1	C2
Ad1	0.60	0.56; 0.56	0.56	0.96; 0.97; 0.96; 0.96	0.89; 0.88; 0.90; 0.87
Ad2	0.81	0.80; 0.82	0.85	0.95; 0.97; 0.93; 0.96	0.87; 0.85; 0.91; 0.88

MP-46

Differential effects of robotically- versus manually-assisted locomotor training on stepping performance after incomplete spinal cord injury

A.L. Behrman[1], L. Fuller[1], S. Stickles[3], K. Day[2], P. Nair[2], C. Phadke[2], M. Bowden[1] and S. Kautz[1]

[1]Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA, [2]Physical Therapy, University of Florida, Gainesville, FL, USA and [3]Physical Therapy, Shands Hospital, Gainesville, FL, USA

Introduction: Walking for successful community ambulation is a complex task requiring the ability to 1) reciprocally step, 2) maintain upright posture and equilibrium, and 3) adapt to the environment and individual behavioral goals. Spinal cord injury (SCI) compromises each of these essential control requirements. A therapeutic strategy to improve walking ability should thus address these sub-tasks. Currently, we do not know what sub-task(s) of walking or if all sub-tasks improve due to a specific training mode. The primary objective of the current study is to assess if there is a differential effect of robotically-assisted versus manually-assisted locomotor training (LT) in the body weight support and treadmill (BWST) environment on stepping performance. We hypothesized that robotically-assisted training will have a greater effect on improving the stepping pattern whereas manually-assisted training will have a greater effect on improving step transition and propulsion.

Methods: Twenty-four adults with incomplete SCI (ASIA C or D) and moderate to severe ambulatory disability (walking speed < 0.8 m/s) will be randomized to robotic-assisted or manually-assisted LT and evaluated for stepping performance on the treadmill. Five subjects to date have completed the training and gait analysis including trunk/limb kinematics and kinetics. Dependent variables include foot trajectory (stepping pattern from toe-off to heel strike), trunk/hip angles (step transition from stance-to-swing) and peak anteriorly-directed ground reaction force during terminal stance (step propulsion).

Results: Preliminary results support the heterogeneity of stepping impairments in the population of individuals with incomplete SCI. Post-training, improvements in foot trajectory, trunk/hip angle, and step propulsion during treadmill walking have been observed.

Conclusions: Preliminary pre- and post-training data demonstrate use of the control model for walking to compare therapeutic approaches and mechanisms of response to interventions. By informing clinicians of the distinct capacity of the mode of training within a locomotor training protocol to improving stepping ability, therapists may better select appropriate strategies targeted to the needs of the individual patient. Clinical decision-making and ultimately walking recovery will improve for individuals after SCI.

MP-47

Effects of Practicing Tandem Gait with and without Trunk-Tilt Biofeedback in Subjects with Unilateral Vestibular Loss

M. Dozza[1], C. Wall III[3], R.J. Peterka[1], L. Chiari[2] and F.B. Horak[1]

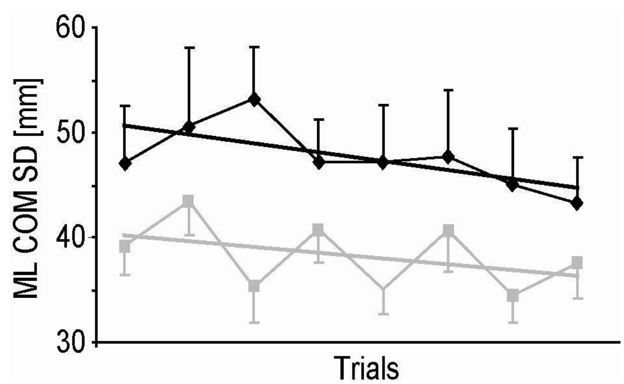
[1]Neurological Sciences Institute, Oregon Health & Science University, Beaverton, OR, USA, [2]Department of Electronics, Computer Science, and Systems, University of Bologna, Bologna, BO, Italy and [3]Department of Otology and Laryngology, Harvard Medical School, Boston, MA, USA

Introduction: Biofeedback (BF) devices have been showed to improve postural control, especially when sensory information is limited by environmental conditions or pathologies such as unilateral vestibular loss (UVL). However, the extent to which BF could improve motor performance or learning while training a dynamic task such as narrow gait is still unknown.

Methods: 9 UVL subjects performed 2 practice sessions consisting of 24 tandem gait trials while wearing a trunk-tilt BF device (C. Wall III, 2001). Subjects were asked to take 1 step for each beat from a metronome (30beats/min) with eyes closed. Subjects were divided into 2 groups. The 1st/2nd group performed the 1st/2nd session with the BF turned on and the 2nd/1st off. When the BF was on, it vibrated up the side of subjects' torso, depending on the amplitude and velocity of their medial-lateral trunk tilt. From motion analysis and tilt data 1) the standard deviation (SD) of the trunk-tilt (indicator of use of BF), 2) the SD of the center of mass displacement (indicator of stability), and 3&4) the variability of stepping placement and the frequency of stepping errors (indicators of accuracy in performing tandem gait) were calculated.

Results: By practicing tandem gait, subjects reduced their trunk-tilt SD, center of mass SD, variability of stepping, and frequency of stepping error. In both groups, use of BF consistently increased postural stability during tandem gait. After practicing with BF, only the stepping frequency parameter was still significantly reduced compared to its value before the BF practice session.

Conclusions: Use of tactile BF consistently improved performance of a dynamic locomotor task in patients with UVL. However, one session of practice with BF does not result in many after-effects consistent with retention of motor performance without this additional BF. Tactile BF acts similar to natural sensory feedback in reducing sensory noise to improve dynamic motor performance and not as a method to recalibrate motor performance to improve function after short-term use.



Effect of practicing tandem gait overtime without BF (black) and with BF (grey). Each value represents the mean among 9 subjects of 3 consecutive trials.

MP-48

The Effects of Rotational Platform Training on Balance and ADLs: Preliminary Results

D.M. Wrisley, N.A. Kumar, D.R. Nunn and M.J. Stephens

Rehabilitation Sciences, University at Buffalo, Buffalo, NY, USA

Introduction: Patients with vestibular dysfunction complain of postural instability and disorientation long after the central compensation is thought to be complete. Previously it has been demonstrated that patients with unilateral vestibular loss who orient more to vertical have better perceived functional status. We proposed that performing balance training with surface perturbations at velocities that target the vestibular system would lead to increased reliance on vestibular information, and therefore improve function. The purpose of this study was to determine whether patients who train using repetitive platform perturbations at these vestibular dependent velocities demonstrate improved postural stability and greater functional abilities than patients who perform traditional balance therapy.

Methods: Eleven patients with chronic vestibular and balance dysfunction (age 58 ± 15 years; 3 males, 8 females) and 4 healthy

control subjects (age 62 ± 23 years; 4 females) participated. Patients were randomized into 3 groups: clinical balance training (CBT n=3) and training with ramp platform perturbations (4 deg amplitude) either at vestibular (1, 2, 4 deg/sec; VESTIB n=6) or at non-vestibular velocities (0.5, 8, 16 deg/sec; Non-VESTIB n=3). The healthy control subjects completed training at vestibular velocities. Subjects' kinematic and kinetic responses to ramp rotational platform perturbations (0.5, 1, 2, 4, 8, 16 deg/sec at 6 deg amplitude), and scores on the Activities-specific Balance Confidence Scale (ABC), Dizziness Handicap Inventory (DHI), Vestibular Activities of Daily Living Scale (VADL) and Functional Gait Assessment (FGA) were compared before and after the 2 week, 3x/week training sessions.
Results: Control subjects demonstrated minimal change in orientation to vertical during platform rotations following training. The VESTIB group demonstrated greater improvements in orientation to vertical during ramp perturbations following training than the Non-VESTIB or CBT groups. Both the CBT and VESTIB groups demonstrated improvements on a composite clinical score incorporating the ABC, DHI, VADL, and FGA following training whereas the Non-VESTIB group did not demonstrate improvement.
Conclusions: These preliminary results indicate that training using platform rotations may be an effective intervention for improving postural control following vestibular loss. Further research is needed to explore the efficacy of incorporating rotational platform training with clinical balance training. Supported by the New York Physical Therapy Association Research Designated Fund

MP-49

Training trunk control in patients post-stroke using virtual reality

L.A. Knaut[2], S. Subramanian[3], A.K. Henderson[4], R. Dannenbaum[1], C. Beaudoin[1] and M.F. Levin[3]

[1]Research, Jewish Rehabilitation Hospital site of Centre for Interdisciplinary Research In Rehabilitation (CRIR), Laval, QC, Canada, [2]School of Rehabilitation, University of Montreal, Montreal, QC, Canada, [3]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [4]Neurology and Neurosurgery, McGill University, Montreal, QC, Canada

Introduction: Stroke is the third leading cause of death and leads to long-term sensorimotor dysfunction in the arm in a large number of patients. Although some arm motor recovery does occur post-stroke, its unclear whether improvements result from true recovery of pre-morbid movement patterns or by means of motor compensations. Behavioral recovery may be characterized by improvements in joint ranges of motion whereas behavioral compensations may be evidenced by increased trunk movement during reaching for example. The incorporation of the trunk into the reaching pattern may be due to a deficit in the ability to dissociate arm and trunk movement and/or problems in trunk control. Improvements in function result from experience-dependant plasticity. Its well known that for induction of experience dependant plasticity, training has to be salient, repetitive, motivating and fun. Recent research has shown that training incorporating all these elements, without incorporation of feedback about the movement performance, may encourage appearance and reinforcement of compensatory movement patterns. Virtual Reality environments (VEs) provide us with a platform through which we can incorporate the feedback elements necessary for optimal recovery to occur. The objective of our study was to determine whether training arm pointing movements in VEs lead to a decrease in trunk movement and improvements in arm motor patterns and movement quality compared to training in physical environment (PEs) in patients with hemiparesis.
Methods: Subjects aged 19–75 yrs who had a stroke <3 yrs previously and mild-to-severe motor impairment participated. Clinical evaluations of impairment (motor impairment– Reaching Performance Scale Fugl-Meyer Scale; spasticity–Composite Spasticity Index,) and function (Box and Blocks Test, Wolf Motor Function Test, Motor Activity Log) as well as kinematic analysis of a pointing task (Optotrak,120Hz,6 markers) was done before and immediately after practice. Subjects practiced varied pointing movements (72 trials/session) daily over 10 days during 2wks, in either a PE or VE. The task was to point as quickly and accurately as possible to 6 targets(12 trials/target, randomized) placed in front of the subject in different workspace areas. In PE, the targets consisted of 6cm^2 squares placed at 2 heights at arm's length. In VE, the targets, identical to PE, were viewed via a head-mounted display in fully immersive and interactive virtual environment. Feedback regarding both knowledge of performance (excessive forward trunk displacement) and knowledge of results (speed and accuracy) was provided after each trial.
Results: After training, movements made by subjects in both groups improved. Preliminary results suggest that participants who trained in the VE had fewer compensations and better arm movement pattern measures
Conclusions: Training in virtual environments may offer a motivating and challenging environment for rehabilitation applications to regain trunk control in patients with stroke.

MP-50

Training dual tasking during gait in Parkinson's Disease

S.G. Brauer[1] and M. Morris[2]

[1]Physiotherapy, The University of Queensland, Brisbane, QLD, Australia and [2]Physiotherapy, University of Melbourne, Melbourne, VIC, Australia

Introduction: Despite studies showing the serious effects of dual task interference on gait parameters in Parkinson's Disease (PD), to date there have been no investigations of the effects of practice on dual task interference during locomotion. As motor learning literature emphasises the importance of task specificity, to optimize training time, knowledge of transfer of training between tasks is needed. The aim of this study was to determine if dual task training of one type of added task during gait leads to improvements in dual tasking with other types of tasks.
Methods: Gait performance under single and six dual task conditions was tested at baseline and immediately after one twenty-minute dual task training session in 14 people with ideopathic Parkinson's Disease. Stride length and gait speed were measured over 8m using a GAITrite® gait mat system under the conditions of gait only, and gait plus: carrying a tray, transferring

coins between pockets, word generation, counting backwards by 3s, auditory choice reaction time task and a visuospatial task. The added tasks were also performed for 15s in sitting to ascertain a baseline response rate and accuracy. One twenty-minute session of training was performed focussing on improving stride length while concurrently performing cognitive tasks (word generation and counting) with verbal responses. To test the hypothesis that dual task training will have greatest effect on the modality trained, a 2 (time) x 7 (task type) factor repeated measures ANOVA was performed on the gait and cognitive task variables.
Results: Stride length demonstrated a significant time (p=0.005), task (p=0.022) and time x task (p=0.011) interaction. There was a significant increase in stride length when walking and performing all six tasks after training dual tasking with cognitive tasks only. Gait speed showed no time effect (p=0.107), but a task (p=0.006) and a time x task interaction (p=0.015). Following training with a cognitive task, only the gait alone and cognitive task trials showed an increase in gait speed. There was no change in correct response rate from pre to post for any task.
Conclusions: Training to improve stride length whilst concurrently performing a cognitive task led to transfer of improvement in that modality (stride length) when performing all types of added tasks. As there was no change in added task correct response rate, it is unlikely that this improvement in gait was due to a change in prioritization from the added task to the gait task, but that people with PD were able to concentrate on and improve stride length without compromising added task performance. While training gait speed was emphasised less, it led to task-specific improvements where only the cognitive tasks showed improvements after cognitive task training. These findings highlight the importance of gait training specificity and indicate that the strategy of dual task training may be more important than the tasks trained in people with PD.

MP-51

Isolated, voluntary leg movement: is it a necessity for restoration of walking after spinal cord injury?

A.L. Behrman[1], P. Nair[1], M. Bowden[2], K. Day[1], E. Friedman[1], B. Herget[1], C.P. Phadke[1], C. Senesac[1], N. Tester[1], F.J. Thompson[3], P. Reier[3] and D.R. Howland[3]

[1]Physical Therapy, University of Florida, Gainesville, FL, USA, [2]Brain Rehabilitation Research Center, Malcom Randall VAMC, Gainesville, FL, USA and [3]Department of Neuroscience, University of Florida, Gainesville, FL, USA

Introduction: While locomotor training (LT)is recognized as a promising strategy for enhancing locomotor recovery in adults with chronic incomplete spinal cord injury (SCI) and voluntary, isolated movements, a unique contribution of this study is testing the training paradigm as an agent for recovery in the pediatric population after SCI. We had an opportunity to assess the effects of LT on a child with severe, chronic SCI, and no prognosis for recovery of walking.
Methods: Baseline, post-training, and one year follow-up evaluations included assessments of voluntary motor control/strength, sensation, and functional abilities. Through the course of the study, gait assesments were added including gait speed, number of self-initiated vs. assisted steps, amount of walking activity, and degree of independence. LT was provided 5x/wk consisting of 20-30 minutes of step training in the body weight support (BWS) and treadmill environment followed by 10-20 minutes of overground training. Manual trainers provided assistance at the pelvis/trunk and each lower limb.
Results: Upon baseline evaluation, 16 months post-SCI, the child's injury was classified as C8, motor incomplete SCI, ASIA C with lower limb motor score 4/50. Residual leg control was limited to an intermittent, extensor synergy at the hip, knee, and ankle without isolated voluntary movement. The child was non-ambulatory (WISCI II 0/20) using a wheelchair or crawling only with his arms for mobility. Four weeks of locomotor training increased extensor activity and improved trunk control, but produced no effect on the ability to initiate flexion. However, after focusing training to augment afferent input for flexor activity, the child began exhibiting voluntary steps overground one week later. After 9 more weeks of training with no change in voluntary muscle strength, he walked 1600-2400 steps/day overground using a rolling walker and showed some recruitment of arm swing and trunk control during treadmill walking. He attended kindergarten the same year using only a rolling walker for mobility. Following training, the child did not demonstrate automatic postural responses or voluntary, isolated leg movements. One year later, the child maintained his walking status, but still did not exhibit isolated leg movements or postural responses. The rhythmical, patterned activity for walking though was extended to similar locomotor tasks: crawling, cycling, and swimming.
Conclusions: The initial activation of stepping dependent upon the sensory experience of the training environment and locomotor-specific input suggests spinally-generated activity. Subsequent willful initiation of a very basic, context-dependent stepping pattern, in the absence of other leg movement, suggests alternative descending supraspinal motor systems were recruited to activate the spinal pattern generators for locomotion during training. This result challenges the assumption that voluntary isolated leg movements are necessary for recovery of voluntary ambulation.

MP-52

An evaluation of two different exercise regimes during the first year following stroke. A randomised controlled trial

B. Langhammer[1], B. Lindmark[2] and J.K. Stanghelle[3]

[1]Faculty of Health Sciences, Oslo University College, Oslo 4, Norway, [2]Institution of Neurosciences, Uppsala University, Uppsala, Sweden and [3]Faculty of Medicine, University of Oslo, Oslo, Norway

Introduction: To evaluate effects of two different exercise approaches during the first 12 months post stroke on Instrumental Activities for Daily Living, gait performance, balance, grip strength and muscle tone and to investigate explanatory factors for Instrumental Activities for Daily Living.
Methods: Design: A double-blind longitudinal randomised trial of first-time-ever stroke patients. Seventy-five patients were included: 35 in the intensive exercise group and 40 in the regular exercise group. After discharge from acute rehabilitation,

patients allocated in the intensive exercise group had physiotherapy for a minimum amount of 80 hours during the first year. Patients in the regular exercise group were not recommended any specific therapy besides treatment when needed. Main Outcome Measures: Information on Instrumental Activities for Daily Living, 6- Minute Walk Test, Berg Balance Scale, Timed Up and Go, grip strength (Martin Vigorimeter), Modified Ashworth Scale, and pulse monitoring during activities.

Results: Results: One year post stroke both groups showed higher participation in all items of Instrumental Activities for Daily Living and improved 6-Minute walk test, Berg Balance Scale scores, Timed-Up-and-Go and grip strength. At 3, 6 and 12 months of follow-up there were significant differences in favour of the regular exercise group. Berg Balance Scale were related to Instrumental Activities of Daily Living item 2 (R 2 0.63 / 0.67and 7 ($p<0.001$) and 6-Minute walk test to item 7 (R 2 0.06, p=0.02 / 0.40, p=0.06).

Conclusions: Conclusion- Instrumental Activities for Daily Living, gait, balance and grip strength improved to similar degrees in both the intensive exercise group and the regular exercise group. The test occasions themselves were probably strong motivators for training, irrespective of group allocation. 6-Minute walk test and Berg Balance Scale explained to a higher degree Instrumental Activities of daily Living than Timed-Up-and-Go and grip strength.

MP-53

THE DEVELOPMENT AND EVALUATION OF A MULTIFACETED IMPLEMENTATION STRATEGY (PARKNET) TO IMPLEMENT THE DUTCH GUIDELINES FOR PHYSICAL THERAPY IN PARKINSON'S DISEASE

M. Munneke[1], S.H. Keus[2], M.J. Nijkrake[1], G. Kwakkel[3] and B.R. Bloem[1]

[1]Parkinson Centre Nijmegen (ParC), Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [2]Physiotherapy, Leiden University Medical Center, Leiden, Netherlands and [3]Physiotherapy, VU Medical Centre, Amsterdam, Netherlands

Introduction: In Parkinson's disease (PD), physical therapy is often prescribed. In the Netherlands more than 50% of PD patients are referred to an physiotherapist.In 2004 an evidence-based clinical practice guideline for physical therapy in Parkinson's disease (PD) was developed and distributed to all physical therapists in the Netherlands (www.cebp.nl). However, distribution hardly ever results in implementation. Therefore, we developed an implementation strategy and evaluated this strategy.

Methods: The ParkNet implementation strategy consists of six steps: 1) selection of therapists who applied to participate in a small PD expert network; 2) a 4.5 day, competence oriented basic course in covering PD in general, and correct use of the guideline for Physical Therapy in PD; 3) a web-based learning management system which facilitates continuous education (e.g. completing tasks, sharing knowledge, exchanging experiences) combined with feedback from coaches; 4) two-monthly seminars in which PD related topics will be discussed; 5) a decision supporting, web-based electronic patient record which guides the therapist through the guideline; 6) involvement of referring physicians.

Results: The multifaceted implementation strategy has started in eight regions in the Netherlands. Willingness to enrol in a PD network was high. Forty-three therapists are selected and enrolled in a PD expert network. The basic course, the web-based learning management system and the electronic patient dossier have been developed. To evaluate the effectiveness of the implementation strategy, we have started a large cluster Randomised trial, the ParkNet Trial. Sixteen clusters (departments of neurology of general hospitals), localized around three university edical centers, are randomly allocated to an experimental group (network care lusters) or a usual care group (unchanged care). In the network care clusters, the implementation strategy is implemented. We intend to include 800 eligible patients in the 16 clusters. All medical records of participating centres (n=3403) are screened and more than 700 patients enrolled already in our study. All patients will be followed for six months. Primary outcome measures are a patient preference outcome scale for limitations in activities, a Dutch validated version of the Dutch Parkinson's Disease Questionnaire-39 (PDQ-39) Mobility domain, and costs.

Conclusions: A multifaceted implementation strategy aimed at implementation of the Dutch guidelines of Physical Therapy in Parkinson's Disease has been developed and will be evaluated within a cluster randomised trial (ParkNet Trial).

MP-80*

Will visual signals facilitate turning in patients with Parkinson's disease?

M.K. Mak[1], C.W. Hui-Chan[2] and A.E. Patla[3]

[1]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China, [2]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China and [3]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: Change of direction during walking is a complex task. To prepare a turn step, subjects need to register the turn direction and to modify the orientation of body and foot from straight line locomotion to walking in a new direction. Patients with Parkinson's disease (PD) are known to have difficulty in modifying motor performance according to task requirements especially that involving switch of movement direction. Hence turning is problematic for them. Our previous study demonstrated that the use of audio-visual cues as preparatory signals could enhance the sit-to-stand task in PD patients. We therefore set out to examine whether visual cues could also enhance turning performance in these patients.

Methods: Nine PD patients (on medication and with mean Hoehn and Yahr Staging of 2.8±0.7) and 9 healthy elderly completed the study. Subjects were cued to walk straight, or to turn either 30 or 60 degrees to left or right at the mid-point of a 9-m walkway. The cue was a light being lit up at the end of the walkway to indicate the direction before gait initiation as "preparatory" signal, and at mid-point of the walkway with one-stride time to plan and implement a direction change as a "delayed" signal. Three-dimensional kinematic data were recorded to compute the step width of the pre-turn step (pre-TS) and turn step (TS) and the time taken to complete the turn.

Each parameter was analysed with 2-way repeated measure ANOVA with "group" as between factor and "timing of the light signal" as within factor.
Results: Both groups of subjects completed the turn in one-stride duration. In the presence of either preparatory or delayed light signal, PD patients had significantly smaller step width of pre-TS and TS than that of the healthy group ($p<0.01$), and they completed the turn with a longer time ($p<0.05$). However, when preparatory signals were given, both healthy and PD subjects significantly increased the step width of pre-TS and TS ($p<0.001$), and reduced the time taken to complete the turn ($p<0.001$) when compared with those of the delayed signal. In fact, PD patients made similar percentage increase in step width of TS (healthy: by 53 and 77%, PD: by 45 and 77% for 30- and 60-degree turn), and similar percentage reduction in turn time (healthy: by 27%, PD: by 23 and 27% for 30- and 60-degree turn) as those of healthy subjects.
Conclusions: When a delayed visual signal was given, PD patients might not have adequate time to plan and/or to execute the turning action, and they turned with a narrower step and required a longer turn time. When visual cues were given as preparatory signals before gait initiation, patients seemed to be able to use the advanced information about the turn direction to plan and elicit a better turning strategy. As a result, PD patients increased the step width of TS and reduced the turn time to a similar extent as those of healthy subjects. Our findings demonstrated that the use of preparatory visual signals could facilitate turning performance in PD patients.

Development of Posture and Gait

MP-55

The postural evaluation of Idiopathic Scoliosis patients and adolescent control subjects. Implications associated with the estimation of the Centre of Mass

K.F. Zabjek[1] and F. Prince[2]

[1]Physical Therapy, University of Toronto, Toronto, ON, Canada and [2]Kinesiology, University of Montreal, Montreal, QC, Canada

Introduction: Idiopathic Scoliosis (IS) is characterized by a three dimensional curvature of the spinal column that is accompanied by vertebral and thoracic deformity. The complex skeletal disorganization associated with these deformities confounds our ability to discern the role of mechanical and neuromuscular factors that contribute to the progression of the spinal curvature. Approaches to understand associated neuromuscular factors have typically assessed postural control during upright stance. However, current modelling techniques utilised to estimate the position of the Centre of Mass (COM) may not be sensitive to the skeletal deformities present in IS. Recently, techniques have been proposed that are independent of the limitations associated with anthropometric models but have not been directly studied in the IS population. The scope of the present work is to quantify the severity of postural deformities in adolescents with IS and further understand their impact on current techniques utilized to estimate the position and displacement of the COM during upright stance.
Methods: The postural alignment of an initial group of 57 adolescent IS patients was assessed using a 3D motion capture system and categorized according to the type of spinal curvature. The calculated postural parameters included rotation,tilt and lateral shift of the pelvis, thorax and shoulders. A sub-group of 22 IS patients and 18 healthy adolescents was also evaluated using an Optotrak 3D kinematic system, and two AMTI force plates during quiet standing (120s). The position of anatomical landmarks tracked by the Optotrak system served to estimate the position of the COM of both groups using an anthropometric model (COManth). The force plate served to estimate the position of the COM through double integration of the horizontal ground reaction forces (COMgl). The mean absolute difference and root mean square (RMS) difference of the COM position was compared between models.
Results: There were significant differences in both angular (rotation, tilt) and linear measures of postural alignment between each type of spinal curvature in the large cohort of patients. In the smaller group of IS and control subjects a bias in the average A/P and M/L position of the COM was found between the COMgl and the COManth. This bias was significantly greater for the IS than the control subjects for A/P (16 mm vs. 12 mm) and similar for M/L (3.9 mm vs 3.5 mm). The RMS difference between the two techniques over a 120 second trial was also found to be significantly greater in the IS than the control group. These differences were 1.2 mm vs .07 mm in A/P and, 0.7 mm vs 0.5 mm in M/L.
Conclusions: The postural alignment characteristics of IS patients is unique for each type of spinal curvature. The amplitude of difference between the COMgl and COManth techniques in suggests that further research is required to optimise the estimation of the COM in adolescent and IS patients.

MP-56

Joint moment normalization in children from five to ten years old

A.C. de David[1], E. Manfio[2] and A. Avila[3]

[1]Physical Education, University of Brasilia, Brasilia, Distrito Federal, Brazil, [2]Biomechanics Laboratory, Estacio de Sa University, Rio de Janeiro, Rio de Janeiro, Brazil and [3]Biomechanics Laboratory, Santa Catarina State University, Florianopolis, Santa Catarina, Brazil

Introduction: Some dimensionless numbers as in spatial-temporal measurements are already commonly used to describe gait data. However, the use of lower limb length or height in joint moment calculation to correct unequal body size has not been used so frequently in literature(Sutherland,1996). Body proportion in children varies according to their growth. The associated effects of the normalization when using body weight, height or leg length in moment calculation of children are not well documented. The purpose of this study was to compare the peak joint moments in sagittal plane when body weight, height and leg length were used to normalize data of children from five to ten years old.
Methods: Gait data of 30 healthy children were collected by using four synchronized video cameras at 60 f/s,two AMTI plate force(Peak Motus System) and an adjusted version of Helen

Hayes marker set protocol. Weight, height and leg length (greater trochanter to lateral malleolus)were measured.An one-way anova test was used to assess differences statistically significant (P<0.05) at the hip, knee and ankle peak sagittal moments between three age groups (5-6 year-olds,7-8 year-olds and 9-10 year-olds).
Results: Body proportions of leg length and height were similar between three age groups. The amplitudes of peak moments showed significant differences at hip flexion, hip extension and plantar-flexion between the 5-6 year-old group and 9-10 year-old group when only body weight was used for normalization of data. When height and leg length were used with body weight for normalization significant differences were observed only at hip extension between the 5-6 year-olds and the two oldest groups (7-8 year-olds and 9-10 year-olds). There were not significant differences in the knee extensor or knee flexor moments data between age groups in any different methods of normalization. Some differences related to amplitudes in joint moments in children reported in the literature (Cupp et al,1999; Chester et al,2006) can be due normalization process uses only body weight.
Conclusions: The data suggest that differences in hip and ankle sagittal moments from 5-6 to 7-10 year-olds decrease when using height or leg length with body weight to normalization however it seems do not affect knee sagittal moments. It would need to investigate the effect of velocity and dependent changes (Stansfield et al,2003).

Table 1 – Mean peak sagittal joint moment across age groups (Mean ± SD)

	5-6 year olds			7-8 year olds			9-10 year olds		
Peak sagittal moments	Body weight	Body weight and height	Body weight and leg length	Body weight	Body weight and height	Body weight and leg length	Body weight	Body weight and height	Body weight and leg length
Hip flexion	0.79* (0.20)	0.68 (0.15)	1.37 (0.30)	1.01 (0.29)	0.81 (0.22)	1.61 (0.44)	1.09* (0.21)	0.78 (0.15)	1.49 (0.29)
Hip extension	-1.12* (0.16)	-0.96‡ (0.15)	-1.93† (0.31)	-0.89 (0.33)	-0.72‡ (0.26)	-1.43† (0.52)	-0.77* (0.25)	-0.54‡ (0.18)	-1.05† (0.36)
Knee flexion	0.35 (0.11)	0.30 (0.09)	0.61 (0.19)	0.27 (0.25)	0.17 (0.32)	0.44 (0.42)	0.27 (0.16)	0.19 (0.11)	0.36 (0.22)
Knee extension	-0.29 (0.07)	-0.25 (0.05)	-0.50 (0.10	-0.24 (0.09)	-0.16 (0.14)	-0.39 (0.14)	-0.28 (0.07)	-0.20 (0.05)	-0.38 (0.09)
Ankle plantarflexion	1.06* (0.07)	0.91 (0.04)	1.83 (0.09)	1.18 (0.16)	0.95 (0.10)	1.89 (0.21)	1.3* (0.13)	0.92 (0.07)	1.77 (0.15)

MP-57

Relationship between stride time variability and decrease in stride velocity among healthy young adults

G. Allali[1], R. Grandjean[2], F.R. Herrmann[2] and O. Beauchet[3]

[1]Department of Neurology, Geneva University Hospitals, Geneva, Switzerland, [2]Department of Rehabililtation and Geriatrics, Geneva Universty Hospitals, Geneva, Switzerland and [3]Department of Geriatrics, Saint-Etienne Universty Hospitals, Saint-Etienne, France

Introduction: Stride-to-stride variability is a measure of the reproducibility of limb-coordinated movements often taken as an indicator of gait control. Low stride-to-stride variability reflects automatic processes that require minimal attention. Increase in walking speed has been associated with an increase in stride time variability independently of an involvement of attention in gait control. Little information is available about the impact of a decrease in walking speed on stride time variability. Our aim is to investigate whether decrease in self-selected walking speed affects stride time variability among healthy young adults.
Methods: Mean value, standard deviation and coefficient of variation of stride time were collected at -20%, -30%, -40%, -50%, -60%, -70% and -80% of the subject's self-selected walking speed using a GAITRite®-System in 29 young adults (23.3 ± 2.1 years old).
Results: The association between stride time parameters and decrease in walking speed was quadratic. All collected stride time parameters increased significantly while walking speed decreased as compared with walking alone (P < 0.001). The ANOVA model showed that decrease in walking speed (P<0.001) and subject effect (P<0.001) explained the increase in stride time parameters, whereas side effect (i.e. left versus right) was not significant (P=0.971 for mean value, P=0.150 for standard deviation, P=0.288 for coefficient of variation).
Conclusions: Decrease in walking speed is associated with an increase in stride time variability among healthy young adults and should be considered as a confounder while evaluating stride time variability.

MP-58

Development of independent walking in toddlers

Y.P. Ivanenko[1], N. Dominici[2] and F. Lacquaniti[2]

[1]IRCCS Fondazione Santa Lucia, Rome, Italy and [2]University of Rome Tor Vergata, Rome, Italy

Introduction: Many animal species start to walk very early in life, often within hours after birth. The comparatively slow maturation rate in humans is believed to be related to particularly complex development of the central nervous system (CNS) and unique challenges of bipedal balance control. Initial stepping differs from a mature walking pattern. What is special in toddler gait? Here we present an overview of our recent findings on the development of independent walking in toddlers.
Methods: We analyzed the centre-of-body-mass (COM) pendulum behavior, planar covariance of the elevation angles of lower limb segments, EMG patterns and foot trajectory characteristics during both unsupported and supported stepping in toddlers.
Results: The initial movement pattern is known to be characterized by short, quick, rigid steps, disordered vertical hip displacements, considerable trunk oscillations, and the toddler holding the arms away from the body. In addition, the toddler makes a higher foot lift during swing and a flat-footed contact with the ground instead of the heel-toe contact of the adult gait. The classic COM pendulum behavior seems to be lacking at the onset of independent walking. Even when supported through hand contact or trunk stabilization, toddlers still exhibited their idiosyncratic gait pattern. This suggests that walking kinematics in toddlers is not simply driven by postural disequilibrium. In addition, we show that, in contrast to adults, high levels of body unloading systematically modify the foot path in toddlers. The most dramatic phase of maturation of many gait parameters (COM pendulum behavior, planar covariance of the elevation angles, inter-step variability, reciprocal arm swinging, plantigrade gait with heel strike, foot trajectory during swing, trunk stability) takes place during the first months of independent walking, though anthropometrical changes and developmental tunings go on for many years.

Conclusions: The dominant hypothesis regarding templates for bipedal walking in the gravity field is a process of vaulting over an inverted pendulum of the stance limb while simultaneously swinging the contralateral limb in a synchronized fashion. We argue that, despite millions of years of bipedal walking evolution in hominids, the pendulum mechanism of walking is not implemented by newly walking toddlers, suggesting that the CNS may be optimized to discover this mechanism given appropriate (unsupported gait) input. We also propose that the evolutionarily adopted primitive pattern (non-plantigrade gait with a higher foot lift) is beneficial for toddlers as an optimal starting point strategy adapted to the initial state of the control system, that is, undeveloped internal representations of both the support surface and the precise endpoint (foot) position in space at the beginning of independent walking.

MP-59

Lyapunov exponent correlations with range of postural sway as an indicator of delayed development of sitting

N. Stergiou[1], J.E. Deffeyes[1], K. Siu[1], R.T. Harbourne[2], S.L. DeJong[2], A. Kyvelidou[1] and W.A. Stuberg[2]

[1]HPER Biomechanics Lab, University of Nebraska at Omaha, Omaha, NE, USA and [2]Munroe Meyer Institute, University of Nebraska Medical Center, Omaha, NE, USA

Introduction: Early intervention has been shown to give significant advantages to infants with developmental delay. However, identification of those infants who might benefit from therapy is key to optimal results. The purpose of this study was to quantify clinically relevant differences in postural control in infants who were learning to sit, by comparing delayed development (DD) with typically developing (TD) infants.

Methods: Eight DD infants, age 9 to 28 months (mean=14.79, std=2.83); and seven TD infants, age 4 to 9 months (mean=6.22, std=1.15) participated in the study. Infants in the DD group were diagnosed with cerebral palsy (n=4), or were developmentally delayed and at risk for cerebral palsy. Infants came to the laboratory twice per month for a period of four months. Trials consisted of recording anterior-posterior (AP) center of pressure (COP) data at 240 Hz for 8.3 seconds of unsupported sitting on an AMTI force plate. Typically three trials per session were recorded. Range of movement (ROM) and largest Lyapunov exponent (LyE) were calculated from COP data, for 157 trials for each population.

Results: A t-test showed the TD and DD groups were significantly different in ROM, but a z-score of only 0.46 indicated that the distributions overlap considerably. However, by only including trials with low values of the LyE (<.06), the z score for ROM was increased to 3.01, indicating that the DD and TD populations were well separated by this measure.

Conclusions: By using LyE as a screening tool to identify clinically relevant trials, ROM from COP data for sitting infants may be useful in early identification of developmentally delayed infants, and could be a suitably sensitive measure to capture improvements in postural development as a result of different therapeutic interventions.

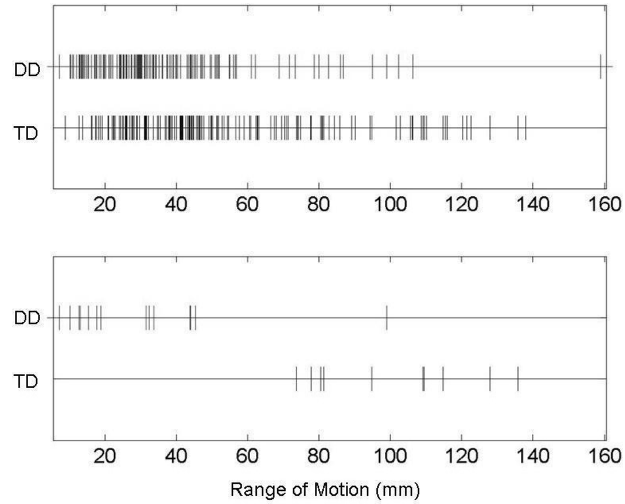


Figure: Distribution of ROM values for all trials (top box) and select trials with LyE < 0.06 (bottom box). Typically developing (TD) and developmentally delayed (DD) populations overlap extensively, unless only low LyE trials are selected.

MP-60

Effects of postural support on eye hand interactions in typically developing children and children with cerebral palsy

S. Saavedra, M. Woollacott and P. vanDonkelaar

Human Physiology, University of Oregon, Eugene, OR, USA

Introduction: Developmental studies examining children with cerebral palsy (CP) have typically documented the delayed acquisition of motor skills. One of the hypothesized causes for these delays is poor balance control. Indeed, postural alignment and stability have been demonstrated to improve the quality of voluntary arm movements in children with CP. Such movements require a complex sensorimotro transformation that takes into account the visual attributes of the object (i.e., location, size, shape, etc), the initial direction of gaze, and the initial position of the hand. This information is then integrated into the planning and generation of the coordinated oculomotor and manual motor output. Anticipatory postural adjustments are required to predictively compensate for the perturbation induced by the movement of the arm. Each of these stages of planning and coordination could be subject to the deficient neural processing associated with CP. Thus, the purpose of this study was to determine the extent to which postural, visual and somatosensory deficits contribute to inaccurate reaching movements in children with CP.

Methods: We examined the functional coupling of the eye and hand across development and determined the extent to which it was constrained by trunk postural control. Participants were children in five categories; typically developing (TD) in 3 age categories (4-6yrs, 7-9 yrs, 10-16 yrs) and children with CP in 2 age categories(7-9 yrs, 10-16 yrs). Head, hand, and eye kinematics were collected with and without external trunk support while subjects performed a series of looking and pointing tasks requiring isolated or coordinated eye and hand movements.

Results: TD children (4-6 yrs) and children with CP (7-9 yrs) had significant difficulty isolating eye movements from head or hand movements, whereas TD children (7-9 yrs) and children

with CP (10-16 yrs) showed improved ability to isolate the eye but continued to have difficulty isolating hand movements from eye movements. By 10-15 yrs TD children demonstrated proficiency in isolating hand movements from eye movements. When postural support was provided the TD 4-6 year olds and children with CP had faster hand movements, whereas the opposite effect was seen in TD 7-9 year olds.
Conclusions: Both trunk postural control and the ability to isolate the different effectors constrain the coordination of eye, head and hand movements during development. We suggest that the complexity of the results reflects the complexity of changing task requirements as both TD children and children with CP transition from simpler ballistic control of all systems to flexible, independent but coordinated control of multiple systems.

MP-61

CHANGES IN GAIT OF THE SOCCER PLAYERS RELATED WITH PAIN SYMPTOMS IN THE LOWER EXTREMITIES

E.F. Manfio[1], A. de David[2] and N. Vilardi Jr.[3]

[1]Biomechanics Laboratory, Estácio de Sá University, Rio de Janeiro, Rio de Janeiro, Brazil, [2]Biomechanics Laboratory, University of Brasília, Brasilia, Distrito Federal, Brazil and [3]Santos Futebol Clube, Santos, São Paulo, Brazil

Introduction: The frequency of soccer injuries are estimated to be approximately 10 to 25 per 1000 playing hours. The majority of injuries occur in the lower extremities, mainly in the knees and ankles. After injuries in the lower extremities frequently occur deviations in gait. These deviations occur of form unknowing; they represent a protection mechanism of the body after an injury. Other problems as the muscular powerless or neurological inhibition can result in compensatory alterations in the gait. The purpose of this study was to compare the sagittal plane joint moments at lower extremities of soccer players physically active with soccer players physically active with pain symptoms in the lower extremities.
Methods: Twenty-four male soccer players participated in the study that were divided in two groups: 9 players healthy, physically active, without pain symptoms or injuries in the lower extremities (S1) and 15 athletes physically active, but with pain symptoms or trauma in the lower extremities (S2). The mean age, height and mass of the S1 were 21.56±1.88 years, 1.81±0.06 m, and 74.09±7.94 kg and S2 were 22.73±2.43 years, 1.76±0.08 m, and 73.64±6.57 kg, respectively. Barefoot gait data were collected using four synchronized video cameras at 60 f/s and two force platforms (Peak Motus System) and an adjusted version Helen Hayes marker set protocol. The mean of three trials was analyzed.
Results: The results showed that there are not significant differences in the temporal-spatial data between groups (velocity was 1.23±0.06 and 1.22±0.12 m/s, cadence 109.23±4.01 and 110.39±5.43 steps/min and stride length 1.36±0.09 and 1.33±0.08 m, respectively to S1 and S2). In the sagittal plane (Table 1), the peak knee extensor moment during the weight acceptance period had been decreased by 48% for the S2 group in comparison to the S1 group.During the mid-stance period, there was a decrease of 12% in the peak knee flexion moment on the S2 group, but no significant differences between groups were found. The ankle plantarflexor moment significant decreased of 15% for the S2 group between the mid-stance period and push-off period. The hip extensor moment and hip flexor moment were similar for both groups.
Conclusions: The results indicate that pain symptoms or trauma in the lower extremities could cause a decrease in the knee extensor moment, knee flexion moment and mainly ankle plantarflexor moment during gait in the soccer players. The appropriate prescription of rehabilitation programs, prevention and training should consider these results.

Table 1–Mean peak sagittal joint moment during gait cycle(Mean±SD).

	S1	S2
Knee extensor	-0.25±0.19	-0.13±0.30
Knee flexor	0.42±0.15	0.37±0.19
Ankle dorsiflexor	-0.04±0.03	-0.08±0.06
Ankle plantarflexor	1.53±0.13*	1.30±0.17*

* Significant differences ($p<0.05$) between groups.

MP-62

DEVELOPMENT OF POSTURAL CONTROL IN HEALTHY CHILDREN

C. Assaiante, S. Mallau, S. Viel, M. Vaugoyeau and C. Schmitz

UMR 6196, DPA, CNRS, Marseille, France

Introduction: When studying the emergence of postural strategies, it is essential to distinguish between results that can be explained by biomechanical reasons strictly and those reflecting the maturation of the CNS. To address this problem, we have studied our young subjects in situations requiring various types of adaptation. The studies dealing with adaptation of postural strategies aimed at testing short and long-term adaptation capacity of the CNS during imposed transient external biomechanical constraints in healthy children, and during chronic internal constraints in children with skeletal pathologies.
Methods: Kinematic data were collected with the SMART motion analyser and the two postural components (orientation and segmental stabilisation) were analysed at head, shoulder, and pelvis levels during various locomotor or postural tasks. The orientation and segmental stabilization of body segments were defined in terms of mean orientation and anchoring index respectively.
Results: From a set of experimental studies showing how intersegmental co-ordinations develop during childhood in various posturo-kinetic tasks, we have established a repertoire of equilibrium strategies in the course of ontogenesis. The experimental data demonstrate that the first reference frame used for the organization of balance control during locomotion is the pelvis, especially in young children. Head stabilization during posturo-kinetic activities, particularly locomotion, constitutes a complex motor skill that needs a long time to develop during childhood. In addition to maintenance of balance, another function of posture is to ensure orientation of a body segment. It appears that the control of orientation and the control of balance both require the trunk as an initial reference frame involving a development from egocentric to exocentric postural control.
Conclusions: It is concluded that the first step for children consists in building a repertoire of postural strategies and the second step consists in learning to select the most appropriate postural strategy depending on the ability to anticipate on the

consequence of the movement in order to maintain balance control and the efficiency of the task.

MP-63

Sensory contribution of postural control as assessed from very slow oscillations of the support in Adolescent Idiopathic Scoliosis (AIS)

S. Mallau, M. Vaugoyeau, G. Bollini and C. Assaiante

CNRS-Marseille, Marseille, France

Introduction: Maintaining erect human posture depends on graviceptive information, that can come from at least of three origins: vestibular, visual and somatesthetic. In young adults, it has been reported that proprioceptive cues alone may be sufficient for vertical orientation of the body. In the other hand, in healthy adolescents it has been reported a transitory proprioceptive neglect to control vertical orientation of the body. Herman et al (1985) postulated that, in the case of idiopathic scoliosis, a sensory (ie proprioceptive) rearrangement or recalibration of the internal representation of the body in space is present, and that a nonerect vertebral alignment may be erroneously perceived as straight. Then, the aim of the study was to mainly explore the proprioceptive contribution to orientation and stabilisation components of postural control in AIS.
Methods: To determine the proprioceptive contribution to postural control, 8 AIS (mean age 14 years 7 month, 10°< angle Cobb< 30°) and 8 control subjects (CS), (mean age 15 years 2 month) were asked to maintain vertical stance while very slow sinusoidal oscillations were being applied in the lateral plane to the platform on which they were standing in upright or in sitting position. The amplitude and frequency of their movements were kept below the semicircular canal perception threshold. Since the frequency threshold at which the vestibular system detects information is 0.2 °/s2, the oscillations were applied at frequencies below this value (0.01 Hz). Data were collected with the SMART motion analyser and the two postural components (orientation and segmental stabilisation) were analysed at head, shoulder, pelvis and cervical, dorsal, lumbar trunk levels while the subjects were performing the task with their eyes open (EO) and closed (EC). The orientation and segmental stabilization of body segments were defined in terms of mean orientation and anchoring index calculated during the whole perturbation cycle.
Results: The results show that whatever the deformity of the spine, the control of the vertical body orientation in standing as well as in sitting position is not affected in AIS. Nevertheless, in response to very slow oscillations, lateral stabilization strategies adopted by AIS contrast with Control Subjects (CS) at cervical level in upright position and at lumbar level in sitting position.
Conclusions: These first results suggest that under static condition the proprioceptive contribution is not altered to control vertical body orientation in AIS whatever the position of the subject on the support. These data support the hypothesis that, in contrast to control adolescents, AIS use more proprioceptive contribution to control vertical orientation probably to compensate a vestibular deficit.
This study is supported by Yves Cotrel Foundation

MP-64

Temporal and spatial dependency of visuomotor control in infant postural development

L. Chen[1], J.J. Jeka[1] and J.E. Clark[1]

[1]*Kinesiology, University of Maryland, College Park, MD, USA and* [2]*Program in Neuroscience and Cognitive Science, University of Maryland, College Park, MD, USA*

Introduction: To control the upright multi-segmented body as environmental conditions change, infants need to develop an adaptive relationship between postural action and sensory information. Adult postural sway shows a frequency-dependent relationship to sensory information (Dijkstra et al., 1994). When stimulus amplitude changes, adults re-weight sensory information to minimize ankle torque necessary for stable and flexible postural control (Oie, Kiemel, & Jeka, 2002; Carver et al., 2005). Sensory re-weighting is a critical component of adaptive sensorimotor control required to maintain upright posture in an ever-changing world. Although vision is suggested as the dominant sense in infants' postural control (Lee & Aronson, 1974), little is known about how infants learn to adapt their posture to different properties of visual information. The purpose of this study was to examine the dynamic visuo-postural relationship and its relation to the properties of visual stimuli in infant postural development. Frequency- and amplitude-dependent properties of infants' postural responses to dynamic visual stimuli were examined during the first year of independent walking.
Methods: In this preliminary study, we examined 6 healthy infants, 3 new walkers (1 week) and 3 experienced walkers (1 year). Infants sat independently on a customized chair. Random triangles were projected on the front wall and two side walls. A video projected in the foveal region with the voice played behind the front wall was used to attract the infant's attention. Three 60-s trials were tested in each of five conditions that varied in the amplitude of visual motion (0~9 cm). Five input frequencies (0.12~1.24 Hz) were presented simultaneously (sum-of-sines) to create anterior-posterior (AP) visual motion. The displacements of infants' head and trunk were measured in the AP direction. Frequency response functions (FRFs) were analyzed for infants' postural responses to various frequency and amplitude properties of visual inputs.
Results: Our results revealed that infants who had been walking for one year exhibited adult-like frequency and amplitude dependency of their postural responses to the visual inputs. Experienced walkers showed systematic decreased gain in their sitting posture as the amplitude of visual inputs increased. Newly walking infants also demonstrated similar frequency and amplitude dependency of their visual-postural relationship except in the lowest amplitude condition (0.72 cm), which showed variable responses. Residual variability was consistently lower in experienced walkers, indicating more stable overall posture.
Conclusions: These results suggest that newly walking infants have well-developed visuo-motor relationships except at very low amplitudes of visual motion where their higher level of self-motion may prevent precise detection. Therefore, we suggest that infant postural development entails a complementary relationship between improved control of self-motion and sensitivity to environmental motion.

MP-65

Development of multisensory reweighting for postural control in children with Developmental Coordination Disorder

W. Bair[1], T. Kiemel[1], J. Jeka[1] and J. Clark[1]

[1]Kinesiology, University of Maryland, College Park, College Park, MD, USA, [2]Program in Neuroscience and Cognitive Science, University of Maryland, College Park, College Park, MD, USA and [3]Program in Bioengineering, University of Maryland, College Park, College Park, MD, USA

Introduction: Postural control is an active process which requires multisensory integration (Horak and Macpherson, 1996) to estimate position and velocity of the body for feedback control (Kiemel, Oie et al., 2002). Sensory reweighting refers to an adaptive process in which sensory inputs are utilized based on their relative importance (Nashner, Black et al., 1982). Downweighting the visual input is observed with increased display amplitude in adults (Peterka and Benolken, 1995) and children (Kim, 2004). Oie et al. developed a new paradigm and showed visual downweighting not only when visual scene motion amplitude increases (i.e. intra-modal reweighting) but also when touch bar motion amplitude decreases while visual amplitude stays the same (i.e. inter-modal reweighting) (Oie, Kiemel et al., 2002). We used the same paradigm in typically developing (TD) children to profile the development of multisensory reweighting for postural control (Bair, Kiemel et al., submitted). Previous studies have shown that children with developmental coordination disorder (DCD) can use a single oscillating visual (Wann, Mon-Williams et al., 1998) or touch input (Chen, Bair et al., 2006) for postural control. The purpose of this study is to examine if children with DCD can reweight to multisensory inputs and how this ability develops.

Methods: The current study includes 17 children with DCD (6.6~11.5 years; 15 boys) whose motor coordination is below 1%ile as assessed by Movement Assessment Battery for Children (MABC). Our previous TD study included 41 children (4.2~10.8 years; 21 boys; MABC >20%ile). Children stood quietly in a semi-tandem stance, looked at a screen with random dots projection and lightly touched a bar with their right index finger. Visual scene and touch bar positions were simultaneously oscillated at 0.2 and 0.28 Hz with 5 amplitude pairs (T8V2, T4V2, T2V2, T2V4 & T2V8; T = touch, V = vision, subscript indicates mean-to-peak amplitude in mm). Three 90-second trials were collected for each condition with 5 conditions randomly presented in each block. Frequency response functions (FRF) to inputs were used to quantify postural responses. Multivariate linear regression of FRF on age was used to examine reweighting across conditions for each group.

Results: In children with DCD, reweighting to both touch and visual inputs is observed for older children while only reweighting to touch input is observed in younger children. In contrast, our previous study showed that TD children reweight to both sensory inputs from 4 years on. Only intra-modal but not inter-modal reweighting is observed in children with DCD. In contrast, visual inter-modal reweighting was observed in older TD children. A dysfunctional touch inter-modal reweighting opposite to the expected pattern is also observed in children with DCD at younger age.

Conclusions: In summary, children with DCD do not only show a delayed multisensory reweighting but also an atypical pattern of its development.

MP-66

Stilt walking: how do we learn those first steps?

S. Akram[1] and J.S. Frank[2]

[1]Kinesiology, University of Waterloo, Waterloo, ON, Canada and [2]University of Windsor, Windsor, ON, Canada

Introduction: Motor learning refers to "a set of processes associated with practice or experience leading to relatively permanent changes in the capability for movement" [1], and is fundamental to human activity. Walking does not come automatically; it must be learned; however, humans master walking to an extent that it becomes almost subconscious. Only when this simple task is compromised due to traumatic injury or neurological damage and must be re-learned, it is realized that our knowledge of motor learning strategies of this assumingly simple task is limited. We investigated stilt walking to expand our knowledge of motor learning strategies of locomotion. Stilt walking is a novel task that introduces some limitations to our normal walking abilities. Stilts elevate the body centre of mass. The mass of stilts modifies the mechanical properties of the lower limbs, further displacing the body centre of mass. Furthermore, the design of stilts does not provide the same range of movement that ankles and feet are capable of when standing directly on the floor, creating the potential for abnormal loads on the knee. Due to these changes and limitations central nervous system may need to adopt alternative postural strategies to allow proper balance control. The objective of the present study was to determine how young healthy adults modify their postural strategies and walking patterns when learning the novel task of stilt walking.

Methods: Ten healthy male university students attended three sessions of testing. On the first two sessions, held in two consecutive days, each participant performed three blocks of 10 stilt walking trials. To test for retention, participants performed ten stilt walking trials on the third session that was held a week from the second session. Angular movements of head and trunk, and the important spatial and temporal gait parameters were recorded.

Results: Results indicate that while walking on stilts young healthy adults improve their gait velocity through modifications of lower limb kinematics while maintaining the trunk in a relatively stable posture. Balance was optimized by consistently increasing the cadence and step length, and reducing the double support percentage of the gait cycle. While learning a novel and challenging walking task it appears that healthy young adults rely heavily on visual information, as the head was kept flexed throughout the course of practice. Results of the retention test revealed that the improved balance performance observed during the acquisition trials was not due to temporary adaptations to the task condition; rather a deeper level of learning has occurred.

Conclusions: Healthy young adults were able to learn the novel task of stilt walking with the amount of practice provided. Learning was achieved mainly through modifications of the lower limb movements. Reference 1) Schmidt R.A. and Lee T.D. (2005). Motor Control and Learning. Fourth Edition. The Human Kinetics.

MP-67

Investigating the contribution of Ia afferent information to the EMG activity of children and young adults during over-ground walking

S.M. McKay and R.M. Angulo-Barroso

Division of Kinesiology, The University of Michigan, Ann Arbor, MI, USA

Introduction: The effects of a brief mechanical tendon perturbation on the ankle trajectory while walking suggests an important role of the proprioceptive signals from the ankle musculature in modulating gastroc-soleus activity (Mazzaro, et al., 2005a,b). In particular, enhancement of dorsiflexion during the stance phase (lengthening of gastroc-soleous) has consistently been associated with increases in plantarflexor activity in adults. In children, contributions of proprioceptive information from ankle muscles to the control of over-ground walking have not been previously investigated. Accordingly, the present study perturbed the output of the Ia afferents during the stance phase via tendon-vibration. It was hypothesized that vibration to the Achilles tendon would result in enhanced muscle activity of the ankle plantarflexors for all subjects. Furthermore, because of less mature nervous systems it was hypothesized that the youngest children would demonstrate further alterations to their responses when vibration was applied.

Methods: The proprioceptive information from the right Achilles tendon was manipulated via unilateral tendon vibration and targeted to the stance phase alone in 30 subjects (5-7, 9-11 and 18-21 years) while walking overground. In total, 10 & 6 trials were collected for each of the older children (OC) and young adults (YA), and young children (YC) respectively for the stance-vibration and control conditions. Bilateral surface EMG were collected from the tibialis anterior (TA) & gastrocnemius (GA) muscles. The following dependent variables were calculated: initial burst start time, initial burst duration, initial burst average amplitude, total average amplitude and number of bursts/s. Analysis of the data was completed using a 3 group x 2 condition ANOVA with repeated measures on condition for each muscle and stance phase per leg.

Results: There was a significant group x condition interaction for GAR average burst activity with increased activity for both groups of children and no change for the YA when comparing the stance- vibration and control conditions ($p<.05$). There was also a significant group x condition interaction indicating an increase in the initial integral and initial amplitude of TAL activity for the young adults while changes were not observed in the children during the stance-vibration condition relative to the control condition ($p<.01$; $p<.01$, respectively).

Conclusions: Vibration is known to primarily stimulate the Ia primary spindles and these findings suggest a relatively smaller contribution to the modulation of GA activity in young adults than children. In young adults, the adjustments to muscle activity may be mediated by additional afferent information. In fact, group II afferents have been proposed to provide a more substantial input during ankle plantar flexors lengthening at the end of the stance phase. Short-latency reflexes are largely depressed in human adult gait. However, the level of attenuation might be smaller in children.

Tuesday, July 17, 2007

Multisensory Integration

TP-1

Differential integration of cues from visual and egocentric frames of reference when perceiving subjective vertical (a preliminary study)

F. Benoit[1], F. Benoit[2], I. Brice[1], B. Delphine[3], V. Nicolas[4], G. Guillaume[2] and A. Michel-Ange[1]

[1]Laboratoire Contrôle Moteur et Perception, Orsay, France, [2]Essilor International, R&D Vision, Saint Maur, France, [3]Input Devices and Music Interaction Laboratory, CIRMMT, Mac Gill University, Montréal, QC, Canada and [4]Laboratoire des Techniques de l'Imagerie, de la Modélisation et de la Cognition - Institut des Mathématiques Appliquées de Grenoble, UMR CNRS 5525, Grenoble, France

Introduction: How humans combine cues from visual and egocentric (kinaesthetic) frames of reference (FR) for determining subjective vertical (SV) still remains an open question. Misaligning these two FR with respect to gravity direction invariably alters the SV. The sensitivity to both visual and kinaesthetic biases is subjected to large and systematic variations among individuals, and would reflect stable preferred modes of spatial referencing (Isableu et al., 2003). Ernst and Bülthoff (2004) suggested that the brain would use probabilistic rules (e.g., Bayes law) for sensory integration to construct coherent and robust percepts (Ernst & Bulthoff, 2004). Thus discrepancies would be always resolved by relying on the most precise modality. The aim of our study was to identify in each subject the rules of combination or integration of cues from visual and egocentric FR when determining SV.

Methods: Subjects (n=8) performed the SV test in visual (V), haptic (H) and visuo-haptic (VH) responses modalities, while being submitted to directional biases in the visual and kinaesthetic FR (either one or both combined). In the V modality, the rod was displayed on a screen and adjusted with the keyboard. In the H and VH modalities, responses were performed using a hand-held graphite rod. In VH the real and the virtual rod were coupled using a Flock of bird™ system. Visual dependency was assessed using a computerised rod-and-frame test (RFT), with a frame tilted to 18°. Kinaesthetic dependency (i.e., dependency to haptic/inertial cues, Pagano et al., 1995; Bernardin et al., 2005) was assessed using a mass distribution alteration system. In this test, the main direction (eigenvector e3) of the head-trunk masses distribution of seated subjects was deviated (based on the Hanavan biomecanical model, 1964) at -9; -4.5; 0; 4.5; and 9 degrees (by appending masses to either sides of the trunk) from the head-trunk longitudinal axis. Visuo-kinaesthetic integration was assessed by comparing the theoretical Bayesian posterior distribution obtained from combining both V and H data to the observed VH data.

Results: As expected, a visual dependence-independence continuum emerged indicating large between-subjects differences in the sensitivity to visual bias ($y=0.906x-1.47$; $r2=.80$;F(1,

14)=9,79; p<.05). Beyond this well-established finding, kinaesthetic (y=0.066x-0.54; r2=.90; F(1,14)=33,35;p<.05) and visuo-kinaesthetic dependence-independence continuum also emerged (y= 0.59x-0.93; r2= .83, F(1, 14)=8,19; p<.05). In addition, the observed VH responses seem to follow the maximum likelihood integrator model (r2= .70, F(1,22)=53,18 ; p<,05).
Conclusions: Preliminary results showed that kinaesthetic cues altered SV settings. Bayesian rules of sensory integration are also used by some subjects to better estimate SV. Data from additional subjects are currently gathered to identify the modes of sensory combination of non Bayesian subjects and to verify the existence of an inverse reliance onto Visual and kinaesthetic references.

TP-2

Sensory responses, motor skills and functional independence in preschool children with autism spectrum disorders

E. Jasmin

McGill University, Montreal, QC, Canada

Introduction: To date, research in autism has been focussed on identifying the gene combination that gives rise to the syndrome of autism spectrum disorder (ASD). Helping these children and their caregivers does not lie within the purview of genetics, but is often the concern of educators and rehabilitation professionals. Within the behavioural domain of the autism spectrum disorders much research focuses on problems of communication, socialization and cognition. However, sensorimotor development, a precondition to communication, socialization, learning and autonomy, remains unexplored. In addition, functional independence such as self-care is little documented in the scientific literature. OBJECTIVE: To determine the sensory responses, the motor skills and the level of functional independence in daily living skills (eating, grooming, dressing and toileting) of children with ASD.
Methods: This project is a pilot and cross-sectional study. 32 children with ASD have been recruited from the Montreal Children's Hospital. Their sensory responses, their motor performance and their functional independence have been assessed using the Sensory Profile, the Peadody Developmental Motor Scales – Second Edition (PDMS-2) and the Functional Independence Measure for Children (Wee-FIM).
Results: A high percentage of children with ASD have atypical sensory responses as measured by the Sensory Profile, but the sensory profile for this sample is not homogeneous. Their average performance on a motor assessment, the PDMS-II, is 2 SD below average in gross motor skills (Quotient = 63.4) and 1.5 SD below average in fine motor skills (Quotient = 74.4). Based on the Wee-FIM, an assessment of daily living skills, their mean performance in self-care is 2 SD below average (Quotient = 55.6).
Conclusions: Interventions will have to be tailored to children's individual needs, because their sensory profile is not homogeneous. Their cognitive and communication difficulties may have influenced their motor performance. The impact of their atypical sensory responses and motor difficulties on functional independence needs further exploration. Before suggesting specific interventions, children's performance should also be compared to children with mental retardation.

TP-3

Characteristics of personal space during obstacle circumvention in physical and virtual environments

M. Gerin-Lajoie[1], C.L. Richards[2], J. Fung[3] and B.J. McFadyen[2]

[1]Cognitive & Linguistic Sciences, Brown University, Providence, RI, USA, [2]Department of Rehabilitation, Faculty of Medicine, Laval University (CIRRIS), Quebec, QC, Canada and [3]School of Physical & Occupational Therapy, McGill University and Jewish Rehabilitation Hospital Research Center (CRIR), Montreal, QC, Canada

Introduction: Walking around obstructions to avoid collisions is an integral part of our daily activities. This common behavior, however, has received relatively little attention compared to other locomotor adaptations such as stepping over obstacles and steering the body in a new walking direction. We have previously shown that the preservation of a personal space (PS), i.e. a safety zone maintained around the body during walking, could be used as a criterion by the locomotor control system to navigate safely around obstacles (Gérin-Lajoie et al., Motor Control, 2005). It is not known, however, how this protective zone is modulated with walking speed, and whether both sides of the PS are symmetrical, or whether the circumvention of physical and virtual obstructions elicit the same use of such a safety zone. Our PS methodology offers a direct quantitative measure of locomotor behavior during obstacle circumvention and is thus well suited to address these issues.
Methods: For the present study, the movements of 10 young adults (22.4 +/- 2.5 yrs) were tracked (100 Hz, Optotrak, NDI, Canada) and their PSs were computed as they circumvented a cylindrical obstacle that was stationary within their path. Participants were informed that the obstacle could either remain stationary (analyzed condition) or move (catch trials) to the right or left during obstacle circumvention by approximately 1.5 m at an angle of 90 degrees with respect to the participant's initial trajectory. Both left and right passes were performed at natural self-selected, slow and fast walking speeds. The same obstacle avoidance task was also performed at natural speeds in a virtual environment (VE) replicating the same obstruction scenario (SoftImagelXSI, SoftImage Co., Canada). Participants viewed the VE through a helmet-mounted-display (KEO Proview XL-50, USA) and the scene was updated in real time (CAREN system, Motek, Netherlands) based on their actual head movement enabling them to interact with this VE.
Results: Results showed that the shape and size of PS were maintained across walking speeds, and that a smaller PS was generally observed on the dominant side. The general shape and lateral bias of the PS were preserved in the VE while its size was slightly increased.
Conclusions: The consistent PS preserved across different speeds and types of environments as well as the systematic lateral bias provide behavioral evidence that PS is used as a criterion to control navigation in a cluttered environment. This study deepens our understanding of normal adaptive walking behavior and has implications for the development of better tools for the assessment and retraining of locomotor capacity in different populations, from people with walking deficits to elite athletes. Since the PS behavior was shown to be robust in the VE used for this

study, virtual reality technology is proposed as a promising platform for the development of such assessment and retraining applications.

TP-4

Intra- and inter-modality reweighting: proprioception and vision

D. Logan, T. Kiemel and J. Jeka

Cognitive Motor Neuroscience, University of Maryland, College Park, MD, USA

Introduction: The ability to select and reweight alternative orientation references adaptively is considered one of the most critical factors for postural control in patient and elderly populations with balance problems.Multisensory reweighting is a crucial component of the process of estimation, in which sensory information from multiple sources is combined to give continuously-updated estimates of the body's position and velocity (i.e., dynamics). Previous studies have shown both intramodality and intermodality reweighting of visual and somatosensory information through the fingertip: a nonlinear process which we refer to as "inverse gain" reweighting. Such reweighting clearly indicates that the sensory modalities are not separable streams of information and provides a strong constraint as to how the nervous system processes multisensory information. Here we tested whether vision and proprioception through the feet/ankles showed similar properties.
Methods: Subjects stood on a movable force platform while surrounded by a 3-wall rear-projected visual cave with randomly distributed 0.2 x 0.2 deg triangles that simulate a fronto-parallel room rotating around the ankle joint. The support platform and visual stimuli consisted of uncorrelated broadband pseudo-random rotations in the AP direction. Three conditions varied the relative amplitude of the stimuli (vision:platform in mm): 1:4, 1:1, 4:1. Kinematic markers attached at 12 joints allowed for calculation of the center of mass and its frequency response function (FRF) relative to the visual and platform stimuli.Frequencies from 0 to 3 Hz were divided into 8 bins, FRFs were averaged within each bin and across subjects, and gain and phase of the average FRFs were computed.
Results: The results showed clear signs of both intra-modality and intermodality reweighting across frequencies. When platform amplitude decreased from 4 mm to 1 mm while visual amplitude remained constant, platform gain increased (intramodality reweighting) and visual gain decreased (intermodality reweighting). Likewise, when visual amplitude decreased from 4 mm to 1 mm, visual gain increased (intramodality reweighting) and platform gain decreased (intermodality reweighting). When stimuli decreased in amplitude, similar but opposite reweighting effects were observed. Changes in gain were most dramatic at lower frequencies. At higher frequencies, gains were smaller and it was more difficult to detect changes.
Conclusions: These results indicate that inverse gain reweighting is independent of modality, that is, a general property sensory fusion that the nervous system uses to form a coherent percept of self-motion.

TP-6

Identifying Postural Control Feedback Using Mechanical Perturbations

Y. Zhang[1], T. Kiemel[1] and J. Jeka[1]

[1]Kinesiology, Univ. of Maryland, College Park, MD, USA, [2]Program in Neuroscience & Cognitive Science, Univ. of Maryland, College Park, MD, USA, [3]Program in Bioengineering, Univ. of Maryland, College Park, MD, USA and [4]Biology, Univ. of Maryland, College Park, MD, USA

Introduction: Models of postural control are based on assumptions and inferences about the frequency response functions (FRFs) associated with processes within the feedback control loop. For example, optimal control models of posture make (often highly simplified) assumptions about muscle dynamics, body dynamics, sensory dynamics and time delays. Based on these assumptions, the models make predictions about state estimation and the control strategy. Ideally, to test the assumptions and predictions of a model, one would like to identify the FRF associated with each process inside the feedback loop. This is not feasible, but it is possible to identify certain combinations of FRFs using a method developed by Fitzpatrick et al (1996), who empirically identified the properties of the plant (the mapping from motor commands to sway) and feedback (the mapping from sway to motor commands) during standing. Their analysis assumed a single-joint model of the body and was based on measurements of the ankle angle and EMG activity from ankle muscles. Here we extend Fitzpatrick's method of identifying the feedback FRF by using a mechanical perturbation and measuring multi-joint kinematic and EMG time series.
Methods: Weak and continuous mechanical perturbations were applied to the subject by attaching the ends of a spring to the back of waistbelt worn by the subject and a linear positioning table placed behind the subject. The anterior-posterior displacement of the table (the perturbation signal) was a broadband pseudo-random time series with frequencies between 0 and 3 Hz. The subjects stood on a fixed surface with eyes closed. Kinematic data were used to calculate trunk and leg segment angles in the anterior-posterior direction. EMG signals from eight muscles were collected and full-wave rectified. The FRF from mechanical perturbation to EMG was divided by the FRF from mechanical perturbation to trunk/leg segment angle. The result is an estimate of the open-loop FRF from body segment (trunk/leg) angle to EMG that characterizes feedback control.
Results: Trunk-leg coordination showed an in-phase pattern a low frequencies coexisting with an anti-phase pattern at higher frequencies, indicating that the mechanical perturbation did not change the typical body coordination observed during quiet stance. Preliminary results indicated that the inferred feedback FRF from both leg and trunk angles to EMG activity had gains that increased with frequency. For posterior muscles, phases were near zero at low frequencies and increased with frequency, indicating that EMG activity temporally preceded leg and trunk position.
Conclusions: For a simple posture model with proportional-derivative (PD) control, phase and gain of the feedback FRF increases with frequency, as observed in our data. However, in such a model phase does exceed 90 degrees, whereas we observed phases greater than 90 degrees at high frequencies. Therefore,

our results suggest that postural control involves a mechanism beyond simple PD control.

TP-7

How habitual exercise affects balance control and postural reactions to perturbations? computerized dynamic posturography study with athletes

K. Hayashi[1], Y. Nishihira[1], A. Hatta[2], T. Kaneda[3], T. Higashiura[1] and K. Kamijyo[1]

[1]Comprehensive Human Sciences Physical Education, Health and Sport Sciences, University of Tsukuba, Tsukuba, Japan, [2]Yokohama College of Pharmacy, Yokohama, Japan and [3]Faculty of Human Development, University of Hakuoh, Tochigi, Japan

Introduction: Some previous studies reported postural stability among the specific sports player show good balance. However, the detailed comparison of athletes and age- and gender-matched control participants never reported. This study focused on how habitual exercise affects balance control and postural reactions to perturbations using computerized dynamic posturography (CDP).

Methods: 15 athletes and 15 healthy young adults participated in this study. They were instructed to maintain their balance on the force platform. The EquiTest CDP system was used to change the reliability of participants' sensory information by altering the position of a movable platform and/or fore screen. Test includes six conditions which lasts 20s and each trial is repeated three times. Balance performance is assessed by quantifying body sway with two indicators: the Equilibrium Quotient score (EQ) as an indicator of postural unsteadiness, and the Strategy score as an indicator how much hip strategy exists relative to ankle strategy. EQ and Strategy score is expressed as a score from 0 to 100. We also measured the effect of five repeated rotation perturbations on standing posture to examine whether adaptive process is different within the groups. This test includes two conditions; one is toe-up rotation and another is toe-down rotation. The degrees of postural response against the perturbations were calculated by analyzing the shear forces on the platform. Each of the outcome measures using ANOVA and post-hoc Tukey t-test to examine differences between the groups. Statistically significant for p-values less than 0.05.

Results: A repeated measures ANOVA was conducted to examine EQ and Strategy score. Significant interaction was observed in group x condition, post-hoc test indicating that athlete's EQ was significantly better than condition 2, 3, 5 and 6. No significant interaction was observed in Strategy score between groups. Repeated measures ANOVA was conducted to examine postural response. Significant interaction was observed in group x trial, post-hoc test indicating that athlete's response force on first trial was significantly lower than control group. Add to this, response force on the first trial was significantly higher than response force on the remaining trials 2-5 in both groups.

Conclusions: The result of EQ score revealed that athletes had a better performance level in difficult tasks. Interestingly, their Strategy score showed no significant difference. They seemed to perform same strategy on each condition. This indicates that habitual exercise may promote central nerves system to detect reliable information in order to compensate for their balance. The result of the five repeated rotation perturbations showed that both groups adapted to the perturbation. However, athletes showed a different postural reaction to the first perturbation of the toe-up condition. We concluded that habitual exercise may change postural control when unknown perturbations were given.

TP-8

Aging affects gaze control during upright stance regulation

C. Paquette[1] and J. Fung[1]

[1]School of Physical & Occupational Therapy, McGill University, Montreal, QC, Canada and [2]Jewish Rehabilitation Hospital Research Site, Montreal Center for Interdisciplinary Research in Rehabilitation, Laval, QC, Canada

Introduction: While saccadic and smooth pursuit eye movements are constantly executed to scan the surrounding environment and often executed simultaneously with the regulation of upright balance, the control of gaze in standing has not been extensively studied. The decline in sensory and motor functions associated with the aging process can lead to an increased risk of falling when gaze control is not well coordinated with the regulation of upright balance. The aim of the present study was to compare and contrast the performance of saccadic and smooth pursuit eye movements with and without surface perturbations between elderly and young healthy subjects.

Methods: Twelve elderly (76±3 years) and 19 (26±6 years) young healthy subjects tracked a visual target located 1.25 m in front of them. The visual signal consisted of alternating periods of unpredictable smooth pursuit and saccadic displacements. Three surface conditions were tested during standing: 1) stationary surface, 2) sudden yaw motions of the supporting surface (pseudo-random sequences of surface rotations: 16° or 32° to the left or right) and 3) plantar cutaneous stimulation. During the latter, a mild electric stimulus (square wave pulse of 6 ms duration, 1.5 times above sensory threshold) was delivered to the medial plantar region during trials without surface perturbations, to contrast the effect of anticipation with postural perturbation on gaze responses. The target stimulus was generated with the Eye-LinkI system that also sampled gaze position at 250 Hz. The head and surface motions were captured at 120 Hz using a 6-camera Vicon 512 system.

Results: Elderly subjects followed both saccadic and pursuit targets with significantly less accuracy than young subjects, as shown by the root-mean-square (RMS) of the target-gaze error (elderly 8.2°±0.2° vs. young 9.4°±0.3°, $P<0.01$). In addition, elderly subjects responded to saccadic targets with longer phase lags as revealed by a cross-covariation analysis (elderly 339±21 ms vs. young 274±17 ms, $P<0.01$). As well, elderly subjects executed more catch-up saccades during smooth pursuits than the younger subjects (elderly 3.9±0.1 saccades/s vs. young 3.4±0.1 saccades/s, $P<0.01$). A significant effect of stance condition was observed such that the moving surface and foot stimulation conditions induced larger RMS errors (no surface 8.1°±0.2° vs. surface 9.3°±0.4° vs. foot stimulus 9.0°±0.4°, $P<0.01$) without affecting any of the correlation values in both age groups. Moreover, catch-up saccades during pursuit were significantly more frequent during surface perturbations (surface 4.03.9±0.1 saccades/s vs. no surface 3.4±0.1 saccades/s, $P<0.01$).

Conclusions: Visual tracking abilities decline with advancing age. The presence of a postural perturbation affects tracking precision equally in young and elderly subjects but not the target-gaze phase lags. The deterioration in gaze tracking abilities in the healthy elderly may result from the multiple but minor deficits in many sensory and motor systems.

TP-9

Influence of visual and support surface velocities on head position

K. Dokka[1], R.V. Kenyon[2] and E.A. Keshner[3]

[1]Department of Bioengineering, University of Illinois at Chicago, Chicago, IL, USA, [2]Department of Computer Science, University of Illinois at Chicago, Chicago, IL, USA and [3]Department of Physical Therapy, Temple University, Philadelphia, PA, USA

Introduction: The sensory-weighting model suggests that the central nervous system (CNS) ignores large amplitude visual cues [Oie et al. 2002]. However, we observed that high velocity and large amplitude visual motion dominated head and trunk postural responses when simultaneous visual and support surface perturbations were discordant [Keshner et al. 2004]. To examine if higher velocities of visual motion are ignored during multiple sensory disturbance, we have investigated the influence of visual velocity on head motion during quiet stance when velocity and frequency cues from the support surface did not match those of the visual field.

Methods: Five healthy young adults (30-33 yrs) were exposed to coincident anterior-posterior sinusoidal translations of the visual environment (scene) and support surface. Subjects received 6 scene velocities: 0.8, 2.4, 17, 20, 80 and 120 cm/sec at 0.1 Hz in a random order. Each scene velocity was combined with a support surface translation of 10 cm/sec at 0.25 Hz for 80 sec. In addition, subjects received support surface translations in the absence of visual inputs (DARK) and when the visual motion was matched to natural head motion (NV), i.e. without any driving visual stimulus. For each condition, the power spectrum of the head center of mass (COM) was calculated at the frequencies of the visual and support surface inputs. A one-way ANOVA followed by Tukey-Cramer multiple comparison tests was used to evaluate the power of the head COM at the visual and support surface frequencies (0.1 and 0.25 Hz, respectively) across different visual conditions.

Results: In all subjects, power increased at the visual frequency of 0.1 Hz for the head COM as the scene velocity increased. A significant increase ($p<0.05$) in the power of the head COM at 0.1 Hz was observed with a scene velocity of 120 cm/sec compared to NV, DARK, and scene velocities of 0.8, 2.4, 17 and 20 cm/sec. Power of the head COM also increased at the frequency of the support surface (0.25 Hz) when the scene velocity increased. In particular, a significant increase ($p<0.05$) in the power of the head COM at 0.25 Hz was observed with scene velocities of 80 and 120 cm/sec compared to NV, Dark, 0.8 and 2.4 cm/sec.

Conclusions: These data indicate that higher velocities of visual motion produced larger responses of the head at both frequencies of sensory disturbance. The intra-modal and inter-modal increases in the power of the head COM during coincident visual and support surface translations support earlier findings that subjects incorporate the parameters of multiple sensory inputs into their motor response (Keshner et al. 2004). At least for the head, large velocities of visual motion are not ignored by the CNS. This would suggest that the motion of the visual field can not only impact the response to visual motion, but will modulate the response to motion of support surface as well.

TP-10

Balance recovery is altered following knee anesthetization

W. Gage[1], J.S. Frank[2], S.D. Prentice[3] and P. Stevenson[3]

[1]School of Kinesiology and Health Science, York University, Toronto, ON, Canada, [2]Department of Kinesiology, University of Windsor, Windsor, ON, Canada and [3]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada

Introduction: Recent work has suggested that the knee joint plays a more prominent role in human postural control than has been previously considered (1,2,3). We explored the contribution of the knee joint sensory system to balance recovery following a balance disturbance.

Methods: Six young healthy male adults (26.8 ± 6.6 years) volunteered. Lower limb muscle activity onsets and amplitudes, and whole body kinematics were measured in response to multidirectional support surface rotations prior to and following anaesthetization (AN) of the right knee joint. Muscle activity was recorded from tibialis anterior (TA), medial gastrocnemius (GAS), soleus (SOL), rectus femoris (RF), biceps femoris (BF), and gluteus medius (GMED), bilaterally. Ten cc of 2% lidocaine were injected into the joint space of the right knee. Participants completed 2 blocks of 20 postural perturbation trials; one block was completed prior to knee joint AN, and the second block following AN. The support surface rotated 7.5° at 50°/sec in one of four directions, i.e. pitch forward (toes down; 0°), pitch backward (toes up; 180°), roll right (90°), and roll left (270°). Perturbation direction was completely randomized.

Results: Knee joint AN modified muscle activity onset latencies following frontal plane (i.e. 90°, 270°), but not sagital plane perturbations (i.e. 0°, 180°). BF onset was delayed bilaterally after AN, as was GMED onset on the downhill (DH) side following frontal plane perturbations. Knee joint AN modified the magnitude of muscle activity for both sagital and frontal plane perturbations. Following toes up perturbations, TA activity was reduced bilaterally, and GAS activity was increased bilaterally, late in the response after AN. RF activity was increased in the left limb and decreased in the right limb early in the balance correcting response after AN; right RF activity remained almost 20% lower throughout the remainder of the response. BF activity was increased bilaterally late in the response following toes up perturbations after AN. Following frontal plane perturbations, uphill (UH) RF activity was reduced from approximately 200 ms onward, regardless of perturbation direction. DH BF activity during this same period was increased. Center of mass displacement (COM) was reduced following sagital and frontal plane perturbations, possibly related to increased knee joint flexion. Peak knee flexion, at approximately 300 ms, following toes up rotations were greater after AN. Following frontal plane rotations in either direction, UH knee flexion was greater after AN.

Conclusions: Knee joint AN was associated with altered patterns of muscle activity around the knee joint which contribute to increased knee joint flexion and reduced COM displacement. Unilateral knee joint AN resulted in bilateral changes in the balance recovery responses. 1. Bloem BR et al. (2002). EBR. 142(1), 91-107. 2. Gage WH et al. (2004). Gait Posture, 19(2), 124-132. 3. Gage WH et al. (2006). Gait Posture, in press.

TP-11

Differences in use of sensory information for balance in elite athletes

M.J. Stephens[2] and D.M. Wrisley[1]

[1]Rehabilitation Science, University at Buffalo, SUNY, Buffalo, NY, USA and [2]Exercise and Nutrition Sciences, University at Buffalo, SUNY, Buffalo, NY, USA

Introduction: Vision, vestibular and somatosensory information are the primary senses involved with upright postural control. However, the degree to which each system contributes to the control of balance may vary across individuals and populations. It is known that patients with sensory deficits (i.e. vestibular loss) differ in their reliance on the various sensory systems. What is not known is if elite athletes in different sports might also differ in their reliance on sensory information and if this reliance is related to skill level. Previous research has demonstrated that athletes in various sports have different postural responses to a variety of postural tasks. The purpose of this study was to examine if there were differences in reliance on sensory information (vestibular versus surface) used for balance control between collegiate football players, graduate level dancers, and healthy young adults.
Methods: Five University at Buffalo football players (age 21.6 ± 0.68 years) and five healthy age-and-gender matched control subjects (age 22.8 ± 0.58 years) participated. A cohort of graduate-level dancers is currently enrolled in the study. Subjects' kinematic and kinetic responses to ramp rotational perturbations (1, 2, 4 and 8°/s in anterior-posterior (AP) and medial-lateral (ML) directions) were compared. A ratio of the degree of the subject's trunk tilt to the degree of platform rotation during the period of ramp movement plus one second was calculated. Larger positive ratios indicate more reliance on surface information. Also, 5 types of "sway referencing" (SR) were examine (AP rotation, AP translation, ML translation, Combined (AP and ML translation in combination with AP rotation) with eyes open and Combined with eyes closed). RMS values of the Center of Pressure (CoP) were compared between the groups for each SR condition and a static trial.
Results: In the ML ramp rotations, the football players relied on surface input significantly more than the control subjects at the slower ramp speeds. In the AP ramp rotations, the football players tended to have greater surface reliance, though the difference was not statistically significant. During SR trials, the football players tended to stand more forward towards the balls of their feet and have a larger sway area in general. Our initial analysis indicates that the dancers orient more to vertical during the ramp rotations and demonstrate decreased sway during the SR trials compared to healthy young adults.
Conclusions: These initial results indicate football players rely more on somatosensory information for balance control than healthy young adults, especially in movements medial-laterally. Further work is needed to see if athletes in sports with varying motor and sensory demands differ in their sensory reliance and if this difference has implications for training. Supported in part by the New York Physical Therapy Association Research Designated Fund

TP-12

ANTICIPATORY POSTURAL ADJUSTMENTS ASSOCIATED TO OBSTACLE AVOIDANCE: CONTRIBUTION OF PROPRIOCEPTIVE INFORMATION

H. Ruget[1], L. Mouchnino[1], G. Robert[1], J. Blouin[1] and N. Teasdale[2]

[1]UMR CNRS 6152 Mouvement et Perception, Marseille, France and [2]GRAME Université Laval, Québec, QC, Canada

Introduction: Step over an obstacle is preceded by a characteristic Center of Pressure (CoP) shift, termed Anticipatory Postural Adjustments (APAs) that propel the body mass forward and laterally prior to the first step. The purpose of this study was to know how central nervous system (CNS) modulates APAs when a modification of proprioceptive information from spindles occurs before the initiation of a voluntary movement. We used the vibration of ankle postural muscles acting in the lateral direction to induce modification of the afferent inflow informing on initial standing position. We hypothesized that muscle vibration applied prior the APAs onset would result in a resetting of APAs parameters.
Methods: Twelve healthy subjects were asked to step over an obstacle at a tone signal with the eyes closed. Three seconds vibration was applied 2 seconds before the movement initiation (dynamic situation). Three conditions were tested: No vibration, Right Vibration and Left Vibration. A quiet standing position (static situation) with three seconds vibration was also tested in two conditions: Right Vibration, Left Vibration.
Results: In static and dynamic situation there is a postural reaction toward the side of the vibration. The APAs in the medio lateral direction are characterized by a thrust exerted by the moving leg onto the ground (center of pressure shift toward the moving side) and an unloading of the leading leg (center of pressure shift toward the supporting side). The analysis of these APAs shows an effect of the vibration on the thrust function of the side of the vibration, and no effect on the unloading. Last, there is a modulation of the final position of the malleolus of the leading foot when vibration is applied, thus increasing the final supporting area.
Conclusions: Our results suggest that proprioceptive input, signaling actual standing position, are monitored and appropriately processed by the CNS in order to modulate the initial phase of the APAs. The change in support conditions, influencing APAs in a functionally appropriate manner, shows that the CNS can control APAs on the basis of a continuous update of the initial position.

TP-13

Visual manipulation in maintaining balance and developing proprioceptive awareness in gymnastic balance beam performance

M.A. Tayler, J. Garner and D. Eaves

Sport & Exercise Science, University of Teesside, Middlesbrough, UK

Introduction: The goal-directed action of crossing a gymnastic balance beam is a complex skill involving multisensory integration. In order to maintain balance and posture during such a task visual and proprioceptive receptors provide the performer with information about body position relative to his or her environment. The main aim of the present study was to examine the effect of removing vision during locomotion across a balance beam (acquisition phase) on subsequent full vision performance.
Methods: Thirty novice gymnastic performers were allocated to one of three groups based on pre-test scores. The main dependent variable throughout was time taken to successfully cross a regulation gymnastic beam 30cm from ground level. The pre-test involved 5 trials crossing the beam with full vision and 5 trials with no vision. Group A subsequently performed 50 practice trials walking across the beam with full vision. Group B performed 50 trials walking across the beam after having peripheral vision removed. Group C performed 50 trials walking across the beam with no vision. Immediately after the practice trials, all participants performed a post-test identical to the pre-test. A further retention test (identical to the post-test) was performed 2 hours after the post-test. Data were analysed via administering a 3 (group) x 3 (time; pre, post and retention test) between-within factorial ANOVA for both the full-vision and no-vision data.
Results: All three groups showed a reduction in time taken to cross the beam between pre-and post-test trials for both the full-vision and no-vision conditions. The main significant findings were apparent between Groups A and C. For example, Group A crossed the beam, on average, in 25.9s and 23.5s in the no-vision pre-and post-test respectively. Similarly, the mean time for Group C participants to cross the beam in the no-vision pre-and post-test was 25.1 and 12.4s respectively. Therefore, Group C crossed the beam significantly quicker than Group A during the no-vision post-test. More interestingly, Group C crossed the beam significantly quicker than Group A in the full-vision post-test (3.5 and 2.6s respectively). These differences were still evident during the 2-hour retention test. For example, the mean time taken to cross the beam for Group A in the full-vision and no-vision retention test was 3.6 and 20.4s respectively. The mean time for Group C during the retention test was 2.7s (full-vision) and 11.1s (no-vision).
Conclusions: The main finding from the present study suggested that participants who practiced the balance beam task with no vision outperformed those who practiced with full vision, in both full-vision and no-vision post-test trials. This suggests that when participants are required to focus more on utilising proprioceptive information during the no-vision acquisition, this has subsequent benefits when returning back to normal, full vision conditions. These findings may have implications for skill acquisition processes across a wide age range.

TP-14

Role of extraretinal signal and head position in balance pointing accuracy

M. Simoneau and . Couture

Kinesiology, Laval University, Quebec, QC, Canada

Introduction: One problem the brain needs to solve is the formation of appropriate reference frame for sensorimotor transformations. During upright standing, the vestibular and visual systems signal change in head and eye position, while the somatosensory system monitors motion of the joints as well as changes in muscle state and contact force between the feet and ground. All these sensory channels provide their own information, which are coded in various reference frames, and require complex multisensory integration. For example, if someone with head erect and facing forward sways 5 deg forward, ideally the vestibular system signals 5 deg forward body pitch. In contrast, if the same body motion occurs with the head turned by 90 deg., chin aligned with the left shoulder, the vestibular system signals a 5 deg rightward head roll. Hence, body sway can produce different vestibular signals depending on head position relative to the trunk.
Methods: Participants (n = 16) stood barefoot on an AMTI force plate. A 17-inch monitor was located 1.5 m in front of them. A red cross, displayed on the monitor, represented real-time centre of pressure (CP) position and the white circle the target to attain (70% of maximal CP displacement). To determine the effects of extraretinal signal (red corss movement on the monitor) and head position on balance control, participants performed three conditions. In condition A, they stood upright with their head straight with respect to trunk. Forward/backward tilt of the body led to upward/downward CP movement on the monitor whereas left/right body tilt created left/right CP movement. Participants needed to tilt their body along the sagittal plane to move the CP in the target. In condition B, subject's head still faced the monitor but their whole body was rotated clockwise by 90 deg; their chin was above their left shoulder. Forward/backward tilt of the body yielded a right/left CP movement on the monitor whereas left/right body movement caused upward/downward movement. To attain the target, subjects needed to sway forward. In condition C, subject's position was similar to condition B but forward/backward tilt caused upward/downward CP movement on the monitor and left/right tilt created left/right CP movement on the monitor. To attain the target, subjects had to sway forward.
Results: The analysis of the final angular error revealed that balance pointing was more accurate when the signals were aligned with each other (condition A). In contrast, change in head position (condition B) or when direction of extraretinal and vestibular signals disagreed (condition C), balance pointing accuracy worsen (i.e., mean ± 0.95 CI of final angular error : 3.44 ± 0.47 deg 5.7 ± 0.65 deg and 10.58 ± 2.61 deg, for condition A, B and C, respectively).
Conclusions: These results agree with the suggestion that neck proprioception, vestibular and extraretinal signals are used to form neural representation of space during balance control.

TP-15

Contribution of lower limb somatosensation to perception of linear acceleration in standing posture

Y. Yi and S. Park

Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology, Deajeon, South Korea

Introduction: The central nervous system perceives body motion using multi-sensory cues such as vision, vestibular information, and somatosensation. Among these sensory cues, previous research reported that pressure sense from soles and proprioception of legs, that is, lower limb somatosensation are strongly correlated with the perception of motion in standing posture.

Methods: To determine whether lower limb somatosensory cues contribute to perception of motion in standing posture and which sensation of lower limb plays dominant role, we examined the changes in detection threshold of the movement direction with and without lower limb somatosensory constraints. As lower limb somatosensory constraints, we used ankle brace for proprioception of ankle and compliant support surface for pressure from sole. Subjects experienced four conditions of experiment: no restraint, restrained ankle, reduced tactile sense from sole, and constrained both of them. In each conditions, six healthy male volunteers (aged 21~ 26 years) stood on a servo-controlled translational platform in the dark with barefoot. The series of randomly sequenced single sinusoidal acceleration at 0.25Hz were used as stimulus. The platform was translated to either subject's left or right with peak acceleration magnitude ranged from 0 to 8mG. After each stimulus, subjects reported their perceived direction of motion by pressing hand held buttons. We defined the magnitude of perception threshold as the stimulus at the performance level of 75% using psychometric function.

Results: We found that reduced lower limb somatosensation significantly increased the perception threshold of linear motion. Without constraints, mean threshold was 0.82±0.23mG, while it was 1.23±0.35mG with reduced lower limb somatosensation. Moreover, when restrained pressure cues of sole, the threshold more increased than the reduced ankle proprioception condition.

Conclusions: These results indicate that without visual cues, lower limb somatosensory information affect perception of motion and the pressure sense from sole takes charge of a superior part in these cues. These results suggest that appropriate complement to a sole may be useful for improving the linear motion detection.

TP-16

Cutaneous afferent inputs are integrated into ongoing Anticipatory Postural Adjustments

L. Mouchnino[1], A. Jay[1], H. Ruget[1] and C. Assaiante[2]

[1]CNRS-Université de la Mediterranée, UMR Mouvement & Perception, Marseille, France and [2]CNRS-Université de la Méditerranée, Groupe DPA, Marseille, France

Introduction: When initiating gait, anticipatory postural adjustments (APAs) are characterized by a thrust in the medio-lateral direction followed by an unloading of the stepping leg leading to a shift of the center of mass (CoM) towards the supporting side. The APAs are considered to be essentially controlled through feedforward mechanisms that allowed prediction of the desired final CoM position. The central nervous system is able to scale the horizontal forces exerted onto the ground (i.e. the thrust) in order to accelerate the CoM towards the supporting side. How this thrust is controlled when the foot sole receptors alone are stimulated. The purpose of this study was to identify the role of cutaneous afferents in scaling the APAs after lateral translation of the platform which did not lead to any body movement.

Methods: Seven subjects stood eyes closed on a force plateform that moved lateralward at an acceleration of 0.33m.s-2 to reach a constant velocity of 0.02m.s-1. This translation resulted in a change in the somatosensory cue from the feet sole without modifying vestibular or proprioceptive inputs. Subjects were instructed to step forward as soon as they felt the plateform began to move. The right leg was the leading limb. 3 conditions were performed: right and left translations of the plateform and a control condition, without plateform translation, where the subject initiated a step in response to a "go" signal.

Results: The plateform translation onset was detected by the presence of a lateral shear force. This mechanically driven force was followed by a head acceleration with a long latency (330ms +/-32). This head acceleration was preceded (40ms +/-10) by a thrust exerted onto the ground. Therefore both results suggest that head acceleration was more likely the consequence of the thrust rather than the mechanical consequence of support translation. The key result of this study was the change observed in the duration of the thrust [$F(2,12)=9.27$; $p=0.0036$] according to the translation side while amplitude was maintained constant [$F(2,12)=2.97$; $p=0.09$].

Conclusions: Subjects are able to use predictive information of perturbation side to scale the APAs. These changes in the thrust reflect the accuracy with which the actual standing position is taken into account through sensory input originated from the foot sole in absence of visual, vestibular or proprioceptive stimulation.

TP-17

Usefulness of current balance tests for identifying balance-impaired individuals

H.S. Cohen[1], K.T. Kimball[2], A.P. Mulavara[3], W.H. Paloski[4] and J.J. Bloomberg[4]

[1]Otolaryngology - Head and Neck Surgery, Baylor College of Medicine, Houston, TX, USA, [2]Statistical Design and Analysis, Austin, TX, USA, [3]Universities Space Research Association, Houston, TX, USA and [4]Neuroscience Research Laboratories, NASA/ Johnson Space Center, Houston, TX, USA

Introduction: The accuracy (sensitivity and specificity) of many balance tests is unknown. We compared normals to vestibularly impaired patients on many common tests and studied post-flight astronauts.

Methods: Subjects were adults: 40 normals, 40 patients with vestibular disorders, and 15 post-long duration flight astronauts. Patients were given computerized dynamic posturography (CDP:

Neurocom Equitest), the Berg Balance Scale, the Timed Up and Go test, and the Dynamic Gait Index – and the new Functional Mobility Test (FMT) that we developed: rapidly walking through an obstacle course on compliant foam. Dependent measures were time to complete the course and number of obstacles touched. Astronauts were given CDP and FMT.
Results: Scores were examined first using the cut-offs for normal scores described in the literature, and then with Receiver Operating Characteristic (ROC) curves. Using the previously reported norms, no standard test classified more than 77% of subjects as patients or normals correctly. FMT time was most accurate, correctly classifying 95% of patients and 80% of crewmembers. CDP Condition 5 (eyes closed, sway referenced platform motion) correctly classified 80% of patients, and using high cut-points than the normals classifed 86% of crewmembers. Other tests classified few patients, suggesting they are not accurate. Use of norms based on ROC curves sharpened accuracy.
Conclusions: FMT may be even more useful when combined with other measures. With existing norms, no standard tests, including the "gold standard" of CDP, are really useful for determining which individuals have functionally significant balance disorders. Tests of gait often used in balance clinics were the least useful. Improved tests would benefit clinical care and the manned space program.

TP-18

Control and estimation of posture during quiet stance depends on multi-joint coordination

J.P. Scholz[1], W. Hsu[1], G. Gregor Schöner[2], J.J. Jeka[3] and T. Kiemel[3]

[1]Physical Therapy Department, University of Delaware, Newark, DE, USA, [2]Institute für Neuroinformatik, Ruhr University, Bochum, Germany and [3]Kinesiology, University of Maryland, College Park, MD, USA

Introduction: Estimation and control of the body's spatial position during quiet stance is said to be simplified because control is primarily exerted about the ankle joint control. Both ankle and hip strategies are invoked to account for responses to support surface perturbations (Horak & McCollum 1989), although recent work suggests signatures of both ankle and hip modes even during quiet stance (Creath et al. 2005). Here we examine the hypothesis that all relevant kinematic degrees of freedom are coordinated to stabilize variables important to posture during quiet stance.
Methods: Ten subjects stood with arms folded across the chest for three 5-min trials with and without vision. We investigated Joint coordination both by spectral coherence and co-phase between all possible pairs of joint sway over time and with the Uncontrolled Manifold (UCM) method (Scholz & Schöner 1999) to examine how coordination of all joints simultaneously affect control of the spatial position of the center of mass (CM) and head positions. A sagittal plane geometric model related the position of six sagittal plane joint angles to task variables spatial position of the CM and head. The model was used to estimate the UCM, corresponding to multiple combinations of joint postures resulting in the same value of a task variable. Joint configurations at each point in time were projected onto the UCM and the orthogonal subspace and the variance within each subspace computed. Higher variance within the UCM (VUCM) than orthogonal to it (VORT) indicates the use of flexible patterns of joint coordination to stabilize the relevant task variable.
Results: Spectral analysis showed variation of all joint angles over time. Ankle and hip joints varied the least. Maximum coherence of individual joint angle pairs was typically <0.5, suggesting weak coupling of their motions. Total joint configuration variance was higher in the no-vision (0.0029+/-0.003 rad^2/DOF) compared to the vision condition (0.0019+/-0.002 rad^2/DOF)(t=-3.0 p<0.05). Despite low coherence between individual joint pairs, UCM analysis revealed that all joints were coordinated such that their combined variance had little effect on the spatial position of the CM and head, even without vision. VUCM was significantly higher than VORT (F[1, 9]=10.6, p<0.01) and higher in the no-vision than the vision condition (F[1, 9]=7.8, p<0.05). VORT did not differ between the two vision conditions (p=0.32), nor was there a significant difference in CM variability between the two conditions (t=-1.1, p=0.32). A similar analysis based on a simplified double-inverted pendulum model provided an inadequate account for the observed phenomena compared to the full model (p=0.39). The results reveal a control strategy where all joints are coordinated to stabilize important control variables related to the posture of quiet stance.
Conclusions: The results reveal a control strategy where all joints are coordinated to stabilize important control variables related to the posture of quiet stance.

TP-19

Sit-to-stand and back-to-stand motion under microgravity condition

M. Vaugoyeau and C. Assaiante

UMR 6196, DPA, CNRS, Marseille cedex 20, France

Introduction: Exposure to microgravity appears to be a privileged situation for the study of motor control. Firstly and obviously, microgravity condition suppresses the gravity force, which is usually the main source of imbalance on Earth. The orientation component of posture is then isolated, and may be analysed independently of the equilibrium component. Sit-to-stand (STS) and back-to-sit (BTS) are two of the most commonly executed human movements. They are complex motor tasks characterized by the transfer from one stabilized posture to another requiring the motion of the trunk in the antero-posterior plane, in order to preserve its equilibrium. These two tasks imply that the SNC take into account the gravity constraint. In our experiment, we studied the kinematics of STS and BTS motions under normo (1G) and microgravity (0G)condition in order to analyze the role of gravity constraints on motor planning, control and execution processes of these two motions. Whether the final body orientation depends on the initial posture and/or the type of straightening up movement is the second question raised by this experiment performed in parabolic flights.
Methods: The kinematics analysis was performed with the SMART infrared TV image processing system. Before each trial, the subject was sitting on a chair, feet fixed to the ground, legs 90° bending, head and trunk maintained straight. From this initial position, with their eyes open the subjects had to stand up

(STS), to maintain this position for 4 s and to sit down again (BTS). This task was realised with vision, under 1g and 0g conditions. We studied the kinematics of trunk displacement during STS and BTS motion in 12 subjects under normo and microgravity condition. The trunk orientation after STS motion was also analyzed.
Results: The kinematics of trunk displacements is significantly different between both gravity conditions: In 1G the STS motion implies a trunk inclination in the antero-posterior plane in order to transfer the CM, in 0G, the subjects lose the trunk inclination before the STS motion. The duration of the STS motion decrease under 0G whereas, the duration of BST motion increases . The analysis of final position shows that 0G affects the whole body postural vertical after STS motion.
Conclusions: The kinematic of STS and BST motion were different in both gravity conditions. This implies that SNC immediately takes into account the new environmental constraints provided by the absence of gravity for motor planning, control and execution processes. Moreover, after STS motion, the subjects showed a slight bending of the trunk. This biased trunk orientation might be attributable to the fact that, in order to adopt an upright posture, the subjects had to perform an active movement, itself modified by microgravity condition. These suggest that dynamic feedback information triggered by an active movement might interfere with static somesthetic information contributing to the assessment of the postural vertical.

TP-20

Postural motor learning during body rotation

P. DiZio, A. Bakshi and J.R. Lackner

Ashton Graybiel Spatial Orientation Laboratory, Brandeis University, Waltham, MA, USA

Introduction: In novel perturbing force environments, motor learning restores optimal performance on motor tasks like reaching movements, head movements, and walking. We assessed motor adaptation of postural sway to altered dynamics. Movement-contingent perturbations were created by having subjects sway rhythmically in the anterior-posterior (A-P) plane while standing at the center of a rotating room. A-P sway during rotation generates medial-lateral (M-L) Coriolis force perturbations. Our specific questions were: 1) how is body sway deviated during rotation when subjects attempt to sway A-P by executing A-P motion of center of foot pressure (CP), 2) what compensatory patterns of CP motion do subjects learn in order to re-achieve A-P sway during extended exposure to rotation, and 3) what voluntary and automatic mechanisms contribute to this form of postural motor learning?
Methods: Ten healthy, college-age subjects used a real-time computer display to learn to rock about their ankles and generate A-P motion of their center of mass (CM) while standing with their feet side by side. Then, without the display and full vision, they performed four 25s baseline trials in a stationary environment, 20 trials during 10 rpm, constant velocity rotation, and 10 post-rotation trials. In addition, responses to A-P "falls" created by sudden release of a holding force against the chest were tested right before the onset of rotation and right after rotation ceased. For these tests, we measured the direction of CP motion generated to reverse the fall, in the first 50ms.
Results: A-P sway of CP and CM remained constant (~4cm p-p, ~0.15 Hz) pre- and per-rotation, but M-L sway amplitude increased about fourfold at rotation onset. In the final per-rotation trials, the baseline pattern of A-P, rectilinear body sway was restored but a new CP trajectory emerged. CP paths became straight, diagonal lines angled ~20° to the left during anterior body excursions and to the right during posterior body sway. Post-rotation, subjects initially executed the same diagonal CP path when attempting to rock A-P, resulting in ~20° diagonal CM motion. There was a significant but smaller (~4°) post-rotation shift in the direction of short-latency CP shift automatically generated to recover from a fall.
Conclusions: Rapid motor learning compensates for altered postural dynamics in a rotating environment. Subjects learn new motor activation patterns to restore the desired spatial path of the body. The presence of aftereffects when subjects attempt to sustain the same spatial path when rotation stops suggests the acquisition of an internal model and feed forward compensations. The learning also involves reflex reorganization, as shown by the spatial rotation of short latency CP responses to impulsive perturbations. Supported by NSBRI NA00406, NASA NAG9-1483, NIH RO1AR4854601.

TP-21

The effects of vision and classical ballet training on the control of upright equilibrium during standing

L. Hughey[1] and J. Fung[2]

[1]Research Center (CRIR), Jewish Rehabilitation Hospital, Laval, QC, Canada and [2]School of Physical & Occupational Therapy, McGill University, Montreal, QC, Canada

Introduction: We have previously shown that individuals with and without classical ballet training make different postural adjustments during voluntary leg lifting while the automatic postural responses triggered by unexpected surface tilts appear to be less distinguishable. Since advanced skills training has been shown to improve postural control when presented with altered sensory conditions, we hypothesize that the occlusion of vision will result in different postural strategies used by dancers and non-dancers in the regulation of upright balance following surface perturbations.
Methods: Eleven classically trained ballet dancers and nine controls matched in age, gender and anthropometry were subjected to sudden tilts (10 deg at 53 deg/s) of the support surface in both eyes-open and eyes-closed conditions. The perturbations were delivered randomly in one of 8 directions in the pitch and roll planes (toes-up, toes-down, side-up, and combined diagonals) for a set of five trials per direction. EMG responses were recorded (BTS-TelEMG at1080 Hz) from four agonist-antagonist muscle pairs located at the shank, thigh, hip and trunk. A six-camera (120 Hz) VICON 512 system was used to capture 3D position data from 25mm retro-reflective markers placed on anatomical landmarks. Kinematic data and anthropometric measures were used to define body segments and calculate total body center of mass (CoM). Kinetic data were acquired at 1080 Hz using two

adjacent AMTI force plates mounted within the moveable platform. Resultant center of pressure (CoP) was calculated and corrected for inertial forces due to motion of the support surface.
Results: While larger head and trunk displacements and smaller pelvis displacements in non-dancers as compared to dancers were evident even in the presence of vision, a significant main effect due to group was only present with vision occluded. Knee flexion was also greater in the non-dancer group for all perturbation directions only when vision was removed. No significant main effects on CoM displacement due to group or vision were found, whereas CoP displacements in the mediolateral direction were significantly greater in dancers with the eyes-closed in all directions except pure pitch. A small increase in background EMG activation and slight decrease in EMG response was found for both groups in the absence of vision.
Conclusions: The different kinematic response observed between dancers and non-dancers following unexpected surface tilting is amplified in the absence of vision. Each distinct strategy reveals a behavior similar to that previously reported during leg lifting in which non-dancers adjust the head and trunk to maintain balance while dancers displace the pelvis. Both strategies appear to be effective as CoM displacement and muscle activation is minimized. The increase in CoP displacement in dancers without vision suggests increased use of proprioceptive feedback in the control of upright balance with advanced training.

Techniques and Methods of Posture and Gait Analysis 1

TP-22

A novel multi-resolution method for EMG analysis

L. Hughey[1], D.H. Burns[3] and J. Fung[2]

[1]Research Center (CRIR), Jewish Rehabilitation Hospital, Laval, QC, Canada, [2]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [3]Department of Chemistry, McGill University, Montreal, QC, Canada

Introduction: Specific postural responses to maintain upright balance are triggered by unexpected perturbations of the support surface. We believe that long-term classical ballet training gives rise to different and more refined postural responses, as compared to those of healthy naïve subjects. However, differentiating the EMG response patterns between dancers and non-dancers has proven difficult by conventional analysis techniques. Thus, a more sophisticated approach of EMG analysis was used to detect any subtle differences not revealed by conventional methods.
Methods: Eleven classical ballet dancers and nine active non-dancers were exposed to sudden tilts of the support surface in 8 different directions during quiet stance. Muscle activations from 4 right-sided agonist-antagonist muscles were recorded. The EMG data were examined using a novel genetic algorithm-based multilinear regression approach. To objectively determine integrated regions of the EMG signal which could be different between the two groups, a Haar son wavelet compression of the data was taken. A genetic algorithm-based optimization method was then used on the individual wavelets and the regions representing the maximum difference between the two groups was found. The robustness of the model was assessed by means of a leave-one-out cross-validation.
Results: Results showed that with the inclusion of 3 factors, the wavelets easily separated the two groups with greater than 95% confidence for all perturbation directions. In addition, integrated regions of the EMG from the hip and back muscles were predominately responsible for the group separations. During limb unloading, differences between the groups were defined by adductor and erector spinae activity during the first 500 ms post perturbation onset. Limb loading resulted in group differences as described by early activity of the thigh muscles followed ~100 ms later by activity of the erector spinae. Model results for toes-up rotations resembled those found for limb unloading with the addition of differences in tibialis anterior activity. Toes-down rotations led to group differences which involved rectus femoris activity. In addition, increased between-subject variability was observed within the dancer group.
Conclusions: Our results show that subtle differences in postural control strategies exist between trained dancers and healthy controls, and that these differences revolve around stabilization of the trunk on the pelvis. These findings support our hypothesis that high-level training leads to changes in the plasticity of the control system and are consistent with our earlier findings for voluntary weight shifting in which dancers and non-dancers use the trunk and pelvis differently. This novel approach of EMG signal analysis has enabled us to detect differences in postural responses between trained dancers and non-dancers which could not be revealed by conventional methods.

TP-23

Are age-related impairments in change-in-support balance reactions consistent for different types of balance perturbation?

A. Mansfield[1], C.Y. Scovil[2] and B.E. Maki[2]

[1]Institute of Medical Science, University of Toronto, Toronto, ON, Canada and [2]Centre for Studies in Aging, Sunnybrook Health Sciences Centre (University of Toronto), Toronto, ON, Canada

Introduction: In studying postural control, two balance perturbation methods are commonly used: a) pull at the waist, or b) translation of the support surface. Studies using different types of perturbations to investigate age-related impairments in ability to recover balance have shown mixed results. The discrepancies could be due to differences in the mechanical and sensory stimuli provided by the different types of perturbation, or some other variation in the methodology such as predictability of the perturbation characteristics (e.g. direction) and instructions given to the subject (e.g. respond naturally vs. try not to step). This study compares change-in-support (stepping and grasping) balance reactions evoked by waist-pull (WP) and surface-translation (ST) perturbations in young and older adults.
Methods: Large multi-directional WP and ST perturbations were used to evoke stepping and grasping reactions in young (YA; 20-30 years) and older adults (OA; 65-75 years). Analysis focussed on: 1) stepping to prevent a forward fall, 2) stepping to prevent a rightward fall while walking in-place, and 3) grasping to prevent a backward fall. Perturbation type, direction and onset timing were varied unpredictably. Subjects were instructed to react

naturally but to minimize the number of steps taken in the stepping trials. In grasping trials, they were told to recover balance by grasping a handrail as rapidly as possible. Response characteristics that have been reported to differ between YA and OA were examined: (a) frequency of 'extra' steps and arm reactions, (b) patterns of stepping, (c) step length, and (d) timing of the responses. Repeated-measures ANOVA with perturbation type-by-age interaction was used to compare responses between YA and OA for both types of perturbation.

Results: Preliminary results from five YA and five OA are reported here; data from the complete sample (10 YA and 10 OA) will be presented at the meeting. A perturbation type-by-age interaction was only observed for one variable: age-related delay in biceps latency (grasping) was more pronounced in ST trials ($p=0.031$). For all other measures, aging had a similar effect regardless of perturbation type. Compared to YA, OA exhibited faster foot-off and foot-contact ($p\leq0.022$), responded to lateral perturbations with crossover steps less often ($p=0.058$) and responded to forward-fall perturbations with 'same-leg' multiple-step reactions more often ($p=0.085$). For both age groups, step and grasp timing measures were slower for WP compared to ST ($p\leq0.031$).

Conclusions: Similar age-related differences in the change-in-support reactions occurred in the ST and WP trials, despite perturbation-specific differences in the mechanical and sensory stimuli and the speed of the evoked reactions. Discrepancies between previous studies are likely due to differences in instructional set and/or perturbation predictability, rather than the type of perturbation. Funding: Canadian Institutes of Health Research.

TP-24

A new instrumented method to measure sitting balance in healthy subjects and patients with stroke

I. Van Nes[1], A.C. Geurts[2] and B. Nienhuis[3]

[1]Dept. of rehabilitation, St. Maartenskliniek, Nijmegen, Netherlands, [2]Dept. of rehabilitation, Radboud University Medical Center, Nijmegen, Netherlands and [3]Dept. of Research, Development and Education, St. Maartenskliniek, Nijmegen, Netherlands

Introduction: Based on clinical testing, sitting balance is an important predictor of functional outcome in stroke. Hence, it is important to assess sitting balance objectively to optimize insight in the characteristics of imbalance for better functional prognosis and treatment. This study was performed to determine the stability and responsivity of selected parameters obtained from a chair mounted on a force platform using both simple and complex quiet-sitting conditions.

Methods: Fifteen healthy young subjects (29.2 ± 3.7 years), 5 healthy elderly (56.1 ± 2.6 years) and 23 patients with a supratentorial stroke (63.9 ± 8.4 years) and a post-stroke interval of 5.7 ± 1.6 weeks were included. The healthy young participated in 3 balance assessments at intervals of 2 weeks, whereas the healthy elderly performed only one balance assessment. The patients with a stroke participated in 3 balance assessments at intervals of 6 weeks. Each balance assessment consisted of four 30-sec test conditions: quiet sitting on a stable surface with eyes open and with eyes closed followed by quiet sitting on an unstable surface (air cushion) with eyes open and with eyes closed. For the patients with a stroke, also the Berg Balance Scale was determined at the same moments in time.

Results: The RMS values of the COP velocities (Vcop) in both the lateral (LAT) and the anteroposterior sway directions appeared to be most stable with Coefficients of Variation varying between 11.3 and 24.0% for the healthy young. The Vcop showed no Time effect. As for stroke, only 16 patients were able to perform all balance tests. Compared with the heatlhy elderly, the patients initially showed a higher LAT Vcop, but this effect was significant only for the unstable condition. In addition, there was a Surface x Vision interaction in the patients indicating increased reliance on vision in the LAT direction during unstable sitting. The Vcop of the patients with stroke showed a main effect of Time in both directions of sway for the unstable condition. Postural instability in the LAT direction at the first assessment was negatively associated with the Berg Balance Scale at the last assessment, the eyes open condition explaining 44% of BBS variance and the eyes closed condition explaining 37% of BBS variance ($p<0.05$).

Conclusions: The Vcop appeared the most stable parameter to assess quiet-sitting balance in both directions of body sway, however, the use of an unstable support surface proved to be mandatory to distinguish stroke patients from healthy elderly in terms of LAT sway values and sensitivity to visual deprivation. The association of LAT Vcop with a validated clinical test such as the BBS further underscores the validity of this parameter. Apparently, LAT sway control during quiet sitting on an unstable surface is most critical in post-acute stroke patients. This insight provides possibilities for improving functional prognosis and treatment in the early phase post stroke.

TP-25

Reactive stepping strategies elicited by an electromagnetic lateral release system

T. Egerton, S.G. Brauer and A.G. Cresswell

School of Health & Rehab Sciences, University of Queensland, Brisbane, QLD, Australia

Introduction: Mediolateral postural control and, in particular, reactive lateral stepping strategies are becoming increasingly recognised as important for balance and fall prevention. Understanding the control of reactive lateral stepping is particularly important as falls in this direction are most likely to result in hip fracture. A single reactive outward step may be more effective in safely arresting a fall than multiple steps. However, eliciting repeatable reactive outward steps in a laboratory or clinical environment has proved challenging. This study reports the frequency and timing of outward stepping strategies elicited in response to a release method of lateral perturbation.

Methods: 14 young healthy adults stood on two force platforms with weights attached and suspended from both sides of a belt worn at the hips. Weights from the left side were released via an electromagnet, pulling the subject laterally to the right at the level of the centre of mass. Subjects were instructed to maintain their balance and keep from falling. Responses were videoed and categorised as an outward side step of the right (loaded) leg, an outward side step of the right leg following an inward movement of the left (unloaded) leg, or crossover steps of the left leg toward

the loaded side. Perturbations to the left side were additionally randomly presented, although these were not analysed. Vertical ground reaction forces were sampled to determine the timing of the stepping responses.
Results: All 75 rightward perturbations were analysed. 77% of responses involved an outward step of the right leg; 52% of these were a single outward step, and 25% were in combination with an inward movement of the left leg. 23% of responses were crossover steps of the left leg only. Mean time from weight release to foot off and landing for outward steps on their own were 275ms and 395ms respectively. These responses were initiated and completed significantly earlier than if performed in combination with an inward step of the left leg, with a mean difference between strategies of 98ms for time to foot off and 73ms for time to landing.
Conclusions: The perturbation method was successful in eliciting reactive outward steps in young adults. The proportion of outward (loaded side) steps alone are comparable with the motorised waist-pull method, however the current method resulted in more combination steps. It also led to fewer crossover steps than reported from platform perturbation trials. The more rapid completion of a single step supports suggestions that it is a more successful strategy to prevent falling. This method of eliciting reactive outward steps provides repeatable loading in unpredictable directions, is relatively inexpensive and therefore may also be useful for clinical assessment and training. Investigation of muscle activity patterns and age related differences in responses is ongoing.

TP-26

Should trunk movement or footfall parameters quantify gait asymmetry in chronic stroke patients?

C. Hodt-Billington[1], J.L. Helbostad[2] and R. Moe-Nilssen[1]

[1]Section of Physiotherapy, University of Bergen, Bergen, Norway and [2]Department of Geriatric Medicine, St. Olav University Hospital, Trondheim, Norway

Introduction: The purpose of this study was to investigate if measures of symmetry and regularity during gait differ between chronic stroke patients and a comparison group without known asymmetries. Further, we wanted to decide which gait symmetry parameter has the best ability to discriminate between the two groups.
Methods: Twenty subjects with hemiplegia (mean age 58 years, SD = 8 years) and 57 subjects without known gait asymmetries (mean age 77 years, SD = 5 years) walked six times across a seven-meter walkway at slow, preferred and fast speed. Measures of vertical, anteroposterior, and mediolateral trunk asymmetry were assessed from triaxial accelerometry data. The footfall parameters single support (% of stride time) and step length (m) asymmetry were assessed from data obtained by an electronic walkway.
Results: Vertical ($p<.001$), anteroposterior ($p=.01$), mediolateral ($p=.01$) trunk movement and single support ($p=.03$) showed significant differences in asymmetries between the group of chronic stroke patients and subjects in the comparison group. No difference in step length asymmetry was found between the two groups. Neither single support asymmetry or step length asymmetry showed the ability to discriminate subjects with hemiplegic gait from subjects in the comparison group, while measures of trunk movement asymmetry were able to discriminate subjects belonging to the two groups ($p\leq.001$).
Conclusions: The results indicate that registration of trunk movement should be included when gait asymmetry characteristics of chronic stroke patients are assessed.

TP-27

Ambulatory gait analysis in patients with Parkinson's Disease: toward a minimal sensors configuration

A. Salarian[1], H. Russmann[2], F.J. Vingerhoets[2], P.R. Burkhard[3] and K. Aminian[1]

[1]Lab. of Movement Analysis and Measurement (LMAM), Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [2]Neurology, Centre Hospitalier Universitaire Vaudois (CHUV), Lausanne, Switzerland and [3]Neurology, Hôpital Universitaire Genevois (HUG), Geneva, Switzerland

Introduction: Sensors attached on the body can hinder the natural locomotion of the subjects, especially in patients with movement disorders. We propose an easy to use system that does not rely on any per-subject calibrations to analyze gait in ambulatory conditions with only two sensors on the shanks. In our previous studies, four [1] and three [2] uni-axial gyroscopes attached on lower limbs were used to estimate spatio-temporal gait parameters (GPs). Main hypothesis behind our new method was that the movements of thighs and shanks are not independant during gait; thus by recording only the latter and predicting the former our previous method [1] could be used to estimate all GPs.
Methods: Gait of 10 PD patients and 10 age and sex-matched healthy controls were recorded using 4 uni-axial gyroscopes attached on the lower-limbs. Flexion-extension angles of thigh and shank (FEt and FEs) in each gait cycle were obtained by integrating gyroscope signals. Coefficients of first 6 Fourier series harmonics of FEt and FEs were calculated. Two prediction matrixes (one for each thigh) were trained to predict FEt's Fourier coefficients from FEs's using data of 7 PD patients and 7 controls. The predicted coefficients were used to reconstruct FEt. The accuracy of the system was evaluated using the data of the remaining 3 subjects of each group and an independent database of 229 gait cycles of normal and pathological gait recorded simultaneously by gyroscopes and a camera based system.
Results: 1666 gait cycles (controls: 615, PD patients in OFF: 545 and PD patients in ON: 506 cycles) were used to train prediction matrixes. 887 gait cycles were used to assess accuracy of the system (controls: 295, PD patients in OFF: 267 and PD patients in ON: 325 cycles). The errors in estimation of FEt compared to measurements by gyroscopes were -2.0 ± 5.0 ° (mean ± SD) for controls, -0.9 ± 5.1 and 0.5 ± 6.3 ° for PD patients during ON and OFF state. Compared to the camera based system, the new method had a slightly higher error in finding stride-length (SL) and FEt than the method with four gyroscopes [1] (3.4 ± 7.3 cm vs. -1.0 ± 6.6 cm in SL and -2.0 ± 5.9 ° vs. -3.1 ± 4.4 ° in FEt) but a lower error in finding SL than the method with three gyroscopes [2] (-0.5 ± 8.5 cm).

Conclusions: Attaching sensors on shanks is easy and recorded signals have low skin and soft tissue movement artifacts. Our study shows that prediction of thigh movements using shank movements during gait with acceptable error is possible. The new method can estimate GPs in PD with accuracy comparable to more complex systems. [1] A Salarian, H Russmann, F Vingerhoets, C Dehollain, Y Blanc, PR Burkhard, and K Aminian, "Gait Assessment in Parkinson's Disease: Toward an Ambulatory System for Long-Term Monitoring," IEEE TBME, vol. 51, pp. 1434-1443, 2004. [2] K Aminian, B Najafi, C Bula, PF Leyvraz, Ph Robert, "Spatio-temporal Parameters of Gait Measured by an Ambulatory System Using Miniature Gyroscopes," J. of Biomechanics, vol. 35, pp. 689-699, 2002.

TP-28

What does sway-referencing really do?

R.A. Creath, T. Kiemel and J.J. Jeka

Kinesiology, University of Maryland, College Park, MD, USA

Introduction: A common experimental technique in the postural control literature is to remove or at least attenuate a particular sensory modality and measure how this changes sway behavior. Such changes can then be used to determine how that sensory information is instantiated in the underlying control system. Sway-referencing either the support surface or the visual field is one of these techniques and is often used as a clinical tool for determining balance deficits. However, it is unknown to what degree sway-referencing attenuates sensory input. Here we use a technique to probe the effects of sway-referencing by adding a small sum-of-sines (SOS) stimulus to the sway-referenced signal. Comparing the response to the SOS signal with and without sway-referencing indicates to what degree sway-referencing reduces the coupling.

Methods: In the first of two experiments, we examined sway responses with the support surface for four platform conditions: 1) Stationary (eyes closed all conditions); 2) Sway-referenced (SR); 3) Rotation using a 10-frequency sum-of-sines (SOS) driving signal which produced an unpredictable platform perturbation; and 4) Combined SR with SOS (SR+SOS). The second experiment used the same 4 perturbation conditions with a moving visual scene rather than a moving platform.

Results: A preliminary analysis comparing the SOS and SR+SOS conditions for the moving platform experiment showed reduced gain at the lower frequencies (below 1.4 Hz) when sway-referencing is added to the SOS (SR+SOS), but no differences at the higher frequencies. By comparison, the moving vision experiment showed a decrease in gain for frequencies above .6 Hz, but not at the lower frequencies.

Conclusions: Sway-referencing is often thought to result in increased sway because the nervous system attempts to use information that is no longer reliable. These results suggest a different scenario: the nervous system down-weights sensory information that is no longer providing useful information for the regulation of ankle torque, due to sway-referencing. This scenario is generally consistent with an adaptive model of postural control developed to incorporate sensory reweighting (Carver et al., 2005). However, our finding that the frequency-dependence of down-weighting is different for visual and platform sway referencing requires an extension of our current model.

TP-29

Development of equipped slippers for doctors to record foot-to-ground plantar pressure during ecological gait

F. Chedevergne[1], M. Dahan[1] and B. Parratte[2]

[1]Laboratory of Applied Mechanics, University of Franche-Comté, Besançon, France and [2]Laboratory of Anatomy, University of Franche-Comté, Besançon, France

Introduction: The dynamic plantar print during walk makes it possible to objectify the absence of good health of walk, and also sometimes to identify current pathology and to follow the possible readjustment to healthy walk during care. To quantify such modification, doctors need a reliable equipment, resistant and easily usable, and allowing to acquire the distribution of the plantar pressures exerted by the foot on the ground during natural walk, over many steps. For this aim, no adequate apparatus currently exists on the market. Indeed, force platforms, pressure plates, pressure insoles and plantar contactors, can not totally respond to the medical need. Some of them ask for carefull walk, others record only the pressure between the foot and the sole of the shoe, and last one are to be renewed for each walk. Thus, those systems can only be used in laboratories and not by patients at home or in hospital. The ideal apparatus does not exist yet on the market.

Methods: We are developing such an equipment. Two comfortable medical slippers were equipped with some sensors throughout the way of normal support of the foot during its roll on the ground. The sensors are inserted in holes bored in the sole of the slipper. Thus, the measured pressure is really the one exerted by the foot on the ground, the sole is only useful for keeping the sensors under the precise zones of the foot. We defined eight zones for an adult size: two sensors under the heel, two under the external edge of the foot, three under the metatarsal heads and one under the hallux.

Results: This equipped slipper will make it possible to observe the value of the pressure exerted by each foot on each zone and at every moment of walk. Thus, the presence or the absence of the roll of each foot on the ground will be revealed. The similarity of the length of time of support and of the pressures exerted by the two feet could also be quantified.

Conclusions: This equipment is under development. The validation of the mechanical operation of the sensors was carried out by tests of dynamic compression on approved tensile testing machine. The validation on healthy patients is in hand. Thereafter, the tool will be used in a medical context to judge effectiveness of a medical intervention on hemiplegic patients.

Equipped slippers (on the left) and sensors insertion system (on the right) currently developed.

TP-30

A new method for assessing gait symmetry

K. Shorter[1], J.D. Polk[2], K.S. Rosengren[3] and E.T. Hsiao-Wecksler[1]

[1]Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA, [2]Anthropology, University of Illinois at Urbana-Champaign, Urbana, IL, USA and [3]Kinesiology & Community Health and Psychology, University of Illinois at Urbana-Champaign, Urbana, IL, USA

Introduction: Gait deficiencies are frequently assessed and treated using univariate parameters such as walking speed, step length, foot rotation, and joint range of motion (ROM) (Whittle, Hum Mov Sci, 1996). Gait, however, is a complex system of coordinated movements and such univariate measures fail to provide information on the impact of an affected joint on ipsilateral and contralateral joints. Understanding patterns of correlated joint movements is particularly important for analyses of asymmetric gait. Ratios and symmetry indices between bilateral values of univariate measures have been used to characterize asymmetries (Becker, Clin Orthop Rel Res, 1995). However, these ratios do not provide temporal information of the asymmetry (Sadeghi, Gait Posture, 2000). This study develops a new method to characterize gait asymmetries in subjects with experimentally restricted knee and ankle ROM. Specifically, we assessed how a single joint's behavior impacts the temporal symmetry of other joints by identifying regions of deviation between bilateral joint motions during a gait cycle.

Methods: Ten male subjects (21±2yrs) walked at a preferred speed (3.2±0.4 km/hr) on a treadmill (Proform, Logan, UT) for 3 minute trials. Four conditions were tested: no brace, right knee brace, right ankle brace, and no brace. Braces (DonJoy, Vista, CA) restricted ROM to zero. Kinematic data were collected at 120 Hz (6 camera, Vicon, Oxford, UK) and low pass filtered (8 Hz 4th order zero-lag Butterworth). Six univariate parameters were calculated: ankle, knee, and hip (flex/ext) ROM, step length, step width, and foot rotation at footflat. Regions of deviation (ROD) were determined over the gait cycle to determine (i) which joint angles were affected by the bracing, (ii) when during the gait cycle these effects were most prominent, and (iii) whether the joint angles of the braced limb (B) were larger or smaller than the unbraced limb (U). To calculate each joint's ROD, bilateral differences for braced conditions were compared to baseline (i.e., nonbraced) bilateral differences, and the ROD is defined as the magnitude greater than one standard deviation from the baseline.

Results: Step length, width, and foot rotation showed no statistical difference between braced and unbraced sides. Traditional ROM parameters found differences between sides due to bracing ($p<0.001$). The new ROD technique identified that ankle bracing did not affect symmetry in knee motion but did affect symmetry in hip flexion, particularly at midstance (U>B). Knee bracing affected ankle symmetry during pre-swing (U>B) and early swing (B>U), as well as hip symmetry during both stance and swing (U>B).

Conclusions: Both ROD and traditional methods detect differences in joint movement that result from bracing; however ROD permits detection of the timing, direction and relative magnitude of compensatory movements in unaffected joints during the gait cycle. This approach has broad application to populations requiring rehabilitation, prostheses or orthoses.

TP-31

Normalization of the plantar pressure distribution pattern for foot size and foot angle

N. Keijsers[1], N. Stolwijk[1], B. Groen[1] and J. Duysens[2]

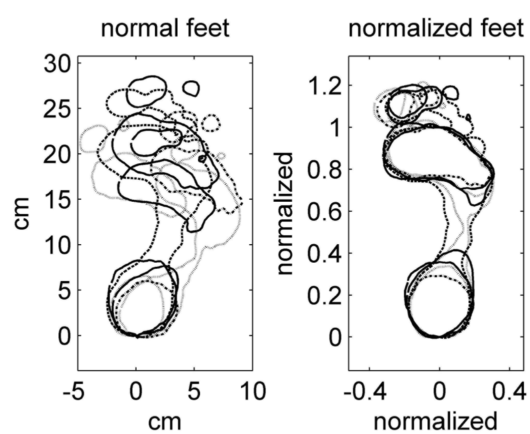
[1]Research Development & Education, Sint Maartenskliniek, Nijmegen, Netherlands and [2]Department of Rehabilitation Medicine, Radboud University Medical Centre, Nijmegen, Netherlands

Introduction: Plantar pressure measurement provides important information about the structure and function of the foot and is a helpful tool to evaluate patients with foot complaints. In general, average and maximum plantar pressure of certain areas under the foot are used to compare groups of subjects. However, masking the foot means a loss of important information of the plantar pressure distribution pattern (ppdp). Ppdp scaled to a standard size and angle would be helpful and more sophisticated analysis techniques could be used. Therefore, the first aim of this study was to develop and test a simple method that normalizes the ppdp for foot size and foot angle. The second aim was to use principal component analysis of the plantar pressure distribution of the normalized foot to differentiate between subjects.

Methods: A total of 160 subjects with various foot complaints walked 5 times over a plantar pressure platform with the three-step strategy. The contour line of 1 N/cm2 of the average plantar pressure distribution was used to calculate the foot angle and foot size. The foot angle was defined as the average angle of the tangents lines to the medial and lateral side of the foot. The foot size was defined as the distance between the back of the heel and the forefoot line. To calculate the normalized foot, the ppdp was rotated over the foot angle and normalized for foot size.

Results: The method was successful in aligning feet with various sizes and angles (see fig.). Further analysis indicated that the ppdp was minimally affected by normalization. Principal component analysis revealed several types of ppdp's. The first and second principal component explained respectively 36.6% and 5.4% of the variance of the ppdp. The first principal component differentiated based on the relative pressure under metatarsal I and II and foot arch.

Conclusions: The proposed method appeared to be successful to align the ppdp of various feet without losing information. Moreover, more sophisticated analysis techniques can be used to analysis ppdp of the normalized foot.



Contour lines of 6 randomly chosen feet before and after normalisation.

TP-32

An index for quantifying deviations from normal ground reaction force

A.M. Muniz[1], M.C. Andrade[2] and J. Nadal[1]

[1]Biomedical engineering program, Federal university of Rio de Janeiro, Rio de Janeiro, Rio de Janeiro, Brazil and [2]Biomechanical Laboratory, State University of Santa Catarina, Florianópolis, Santa Catarina, Brazil

Introduction: In gait analysis, discrete parameters of the ground reaction force (GRF) are being used to analyze normal and pathologic gait. However this approach provides limited insight about the movement. To evaluate pathologic gait or to assess the changes in gait resulting from a specific treatment, it becomes important to analyze the GRF time series, to find some clinical measurement that indicates of how closely an individual gait approaches the normal pattern. The present study uses Principal Component Analysis (PCA) to determine a score to quantify the a abnormality of gait.
Methods: A sample with 51 subjects was organized into two groups: a control group (CG) of 38 healthy subjects (19 to 35 years) and a group of 13 patients (16 to 58 years) with unilateral lower limb fractures (FG). Five subjects from FG underwent treadmill physiotherapeutic treatment (FGA). The subjects walked on a modified treadmill with embedded force platforms (Gaitway® model 9819S1) at a controlled speed (4 km/h). The vertical component of GRF data was collected at 300 Hz for 10 s. PCA was obtained from the mean GRF of each subject. The first two Principal Components (PC) were used to obtain the Mahalanobis distance (MD).
Results: The two PCs represented 50.77% of the total data variance. The CG was delimited in an elliptical area of 97% with a MD of 4.7 from the center of the ellipse of CG data. The MD of the FG and FGA groups was shows in Table 1. Just two FG patients (who had mild injury) reached the normal area. Of the five FGA subjects, just two did not reach the normal area after treatment. However, all presented decreased MD indicating reduced abnormality due to the injury. Thus MD is a reliable score of the degree of alterations of GRF.
Conclusions: The present results point out the potential power of PCA in detecting abnormality in gait pattern and objectively evaluating the progress and effectiveness of treatment.

Subject	FG	FGA
01	51.87	5.02
02	6.74	0.43 *
03	15.15	6.73
04	33.32	1.24 *
05	13.96	1.25 *
06	37.64	NA
07	28.49	NA
08	10.04	NA
09	2.45 *	NA
10	3.02 *	NA
11	43.66	NA
12	40.93	NA
13	8.63	NA

* Inside normal area; NA Data not available

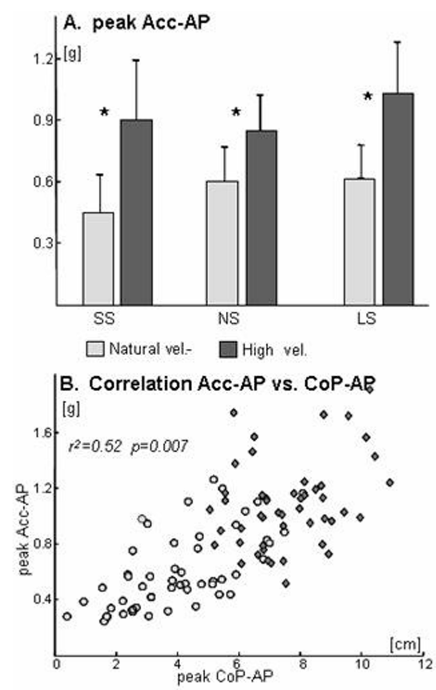
TP-33

A novel approach to investigate anticipatory postural adjustments for stepping based on inertial sensors

L. Rocchi, M. Mancini, A. Cappello and L. Chiari

Department of Electronics, Computer Science and Systems, University of Bologna, Bologna, Italy

Introduction: Anticipatory postural adjustments for stepping (APA) are usually detected by EMG or force platform recordings. Recent advances on miniature, inertial sensors introduce the opportunity to measure movement with low costs and great portability. The aim of the present study was to verify that inertial accelerometers are sensitive to APA in step initiation.
Methods: Thirteen subjects (24.4±2.6 years), with no history of neuromuscolar and skeletal disorders, weared 3 bi-axial accelerometers, mounted on the posterior trunk and on the lower limbs, laterally below the knee of the right and left leg. Subjects were asked to voluntarily take 2 steps, starting from a force platform, at 3 different lengths: short, 35cm (SS), normal, 65cm (NS) and long, 95cm (LS). Three repetitions at natural and maximal velocity were performed. The measurement set-up also included a motion analysis system. The onset of APA was identified by the first measurable change in center of pressure (CoP) excursion, backward and toward the swing limb direction. The gold-standard APA magnitude was quantified by the backward peak of CoP in the antero-posterior direction (CoP-AP).
Results: AP acceleration (Acc-AP) measured on the stance leg was found to be sensitive to step length and velocity similarly to CoP-AP (Fig. 1A). The similar information included in peaks of Acc-AP and CoP-AP was supported by the strong linear correlation found between the two parameters ($r2=0.52$, $p<0.01$, Fig. 1B).
Conclusions: The reliable pattern of Acc-AP suggests possible promising applications of portable sensors in the measurement of movement during daily-life activities, outdoor.



TP-34

Effect of parkinson's disease and levodopa on functional limits of stability

M. Mancini[1], L. Rocchi[1], L. Chiari[1] and F. Horak[2]

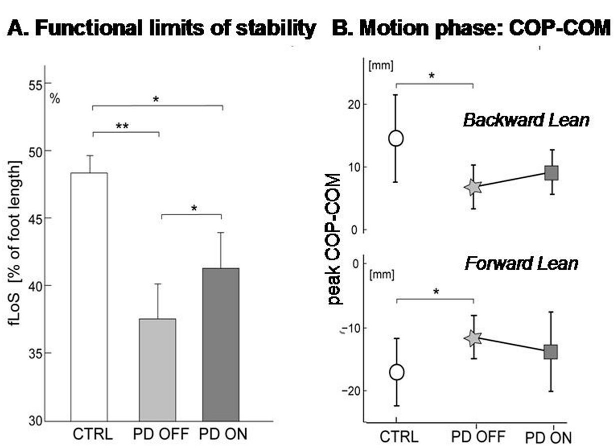
[1]Department of Electronics, Computer Science and Systems, University of Bologna, Bologna, Italy and [2]Neurological Sciences Institute, Oregon Health and Sciences University, Portland, OR, USA

Introduction: Postural instability has a big impact on the quality of life of patients with Parkinson's disease (PD) as it often results in falling, subsequent injury, and increased fear of falling. The aim of the study is to evaluate how subjects with PD and elderly control maintain balance in challenging conditions, such as inclined posture like body leaning that occurs also during the transition from stance to gait

Methods: 14 subjects with PD (OFF and ON levodopa) and 10 age-matched control subjects (CTRLs) participated in the study. Subjects were asked to stay on a dual plate force platform, from which the instantaneous center of pressure (COP) was computed, for 2 types of sequential trials: maximal forward lean and backward lean. Subjects were instructed to lean forward/backward trying not to flex the hips, as far as they could, and keep the position at least for 5s. Subjects were also tested in quiet stance eyes open for 60 s. Acquisition of reflective markers on bony landmarks allowed to calculate the body center of mass (COM). The maximal leaning at steady state was assumed as an indicator of the magnitude of functional Limits of Stability (fLoS).fLoS were defined as the difference between CoP antero-posterior during max forward and backward lean. The motion phase, performed to reach the maximal leaning condition, was studied to describe the preparation and execution of movement and was quantified by peak of the difference between COP and COM (peakCOP-COM).

Results: fLoS were reduced in PD OFF with respect to CTRLs and improved significantly in ON (Fig.1A, means±SEM). Regarding the motion phase, peakCOP-COM was significantly reduced in PD OFF compared to CTRLs and slightly improved in ON (Fig.1B).

Conclusions: Reduced fLoS in PD may contribute to their progressive postural instability. Our results showed that levodopa helps to improve both the maximal leaning phase and the motion phase and this may be due to its important role in reducing rigidity.



TP-35

Knee flexor muscles response to sacral root electrical stimulation during standing and walking

M.A. Lesniak, E. Kadera, C.E. Scott, J.L. Johnson, B.W. Floy, C.R. Peterson, W.G. Darling and M. Ladouceur

Integrative Physiology, The University of Iowa, Iowa City, IA, USA

Introduction: Study of cortical excitability changes during walking requires use of maximum M wave amplitudes to control for movement of recording electrodes. Previous studies of sciatic nerve stimulation have been done when participants were in a prone position. The purpose of this study was to establish the feasibility of recording maximal motor responses (Mmax) in knee flexor muscles during standing and walking.

Methods: Participants with no known neurological disorders were tested while prone, standing, and walking at their self-selected speed on a treadmill. The electromyography (EMG) signal from the Biceps Femoris was recorded using bipolar electrodes (Delsys 2.1) placed over the belly of the muscles with the reference electrode placed around the distal part of the lower leg. The EMG signal was amplified (1000x) and filtered (20-450 Hz). Sacral spinal nerves or their roots were stimulated using a high-voltage stimulator (Digitimer Type D185) at intensities of 0-1.5 A (50 μs duration). The stimulation electrodes (circular, 2 cm diameter) were placed over the L5 spinous process (anode) and the homolateral iliac region (6cm away at a 45 degree downward angle, cathode). Timing of sacral nerve stimulation during walking was controlled using a footswitch taped under the right heel. The EMG and footswitch signals as well as stimulation current was digitized (25kHz) using a custom-made data acquisition software. An on-line analysis of the motor response as a function of electrical stimulation intensity was used to insure that the whole motor recruitment curve was recorded.

Results: Sacral root stimulation generated a multiphasic response in all participants (n=4). The latency of the first response ranged from 5.0 to 7.32 ms. with maximal peak to peak amplitudes ranging from 1.1 to 4.73mV. The latency of the second response ranged from 18.3 to 27.12ms with maximal peak to peak amplitudes ranging from 0.4 to 3.39mV. Maximal values for the first response were recorded in the majority of cases (prone: 3/4; standing: 3/4, walking: 2/3). Maximal values for the second response were recorded less frequently (prone: 2/4; standing: 2/4; walking: 2/3). All participants perceived the electrical stimulation as strong but tolerable even at the maximum output of the stimulator. Changes in amplitude of the second response were seen with a protocol of low-frequency inhibition. Changes in response amplitude with muscle vibration will also be discussed.

Conclusions: Results from this experiment show the feasibility of recording Mmax values for the hamstring muscles while walking in some participants. Preliminary evidence suggests that the first response would be related to direct muscle activation whereas the second response seems to be related an afferent mediated activation.

TP-36

Postural impairment in Parkinson's disease: diagnostic utility of the "first trial effect"

J.E. Visser[1], L. Janssen[1], L.B. Oude Nijhuis[1], C.M. Bastiaanse[2], G.F. Borm[3], J. Duysens[2] and B.R. Bloem[1]

[1]Department of Neurology, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [2]Department of Rehabilitation Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands and [3]Department of Epidemiology and Biostatistics, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands

Introduction: Dynamic posturography, as it is currently used, has limited clinical utility in diagnosing balance disorders and the evaluation of the risk of falling in individual patients. Here, we investigated the diagnostic utility of a new approach, where we analyzed the balance responses to the very first and fully unpracticed trial, rather than a pooled mean response to a series of predictable perturbations.

Methods: We included 14 patients with Parkinson's disease (PD) and 17 age-matched controls. Subjects received a series of multidirectional postural perturbations, induced by support surface rotations. The kinematics of trunk movement and electromyographic responses to the very first trial – which was always a pure backward perturbation – were compared with those induced by a habituated backward perturbation. Electromyographic responses were recorded from the masseter, erector spinae, tibialis anterior and soleus muscles.

Results: The first, unhabituated perturbation induced a large forward flexion of the trunk in controls, and this was decreased in patients. The first trial also elicited smaller electromyographic responses in the tibialis anterior muscle of patients. Interestingly, both groups showed prominent masseter activity with an early onset, suggesting a startle-like response. The amplitude of this early masseter response was significantly increased in patients compared to controls. Masseter activity was not attenuated in the habituated trial, suggesting a persistent startle-like component to the balance response. Trunk flexion and the other electromyographic responses did show significant habitation in both groups, and the rate of this habituation was comparable between patients and controls. Consequently, differences between patients and controls were equally evident for the first trial and the habituated trial.

Conclusions: We observed a clear "first trial effect" in both PD patients and controls, which was associated with early and prominent masseter activity, suggesting the presence of a startle-like component to the overall balance response. Further studies are warranted to disentangle this startle component and to evaluate its role in the pathophysiology of balance disorders. Postural responses were abnormal in PD patients, but equally so for the first trial and the habituated trial. In terms of diagnostic utility, evaluation of the first trial response is no better than the pooled responses to a series of perturbations.

TP-37

Impact of athletic skills on body sway during stance

R. Van Lummel[1], H. Kingma[2] and R. Van der Slikke[1]

[1]R&D, McRoberts, The Hague, Netherlands and [2]Division of Balance Disorders, University Hospital Maastricht, Maastricht, Netherlands

Introduction: Body sway reflects various processes involved with balance control in stance. stance, stabilometry in casu force plates are widely used to quantify body sway parameters. Body sway parameters can also be detected with another methodology. Body fixed sensors (BFS), like accelerometers and gyroscopes, can be fixed on the body close to the centre of body mass and detect body motions and tilts. In this study, we investigate whether body fixed 3D low drift accelerometers and specific signal analysis techniques are able to identify discriminative body sway parameters in stance under various conditions.

Methods: Three groups of bachelor students participated in the study: students from several studies, physical education students and physical education students specialised in gymnastics. Accelerations were measured with a tri-axial piezo-capacitive accelerometer (DynaPort® MiniMod, McRoberts BV, The Hague, The Netherlands). The acceleration module is fixed with an elastic belt near the CoM at L3. Tasks performed can be classified into 2 categories: o Two-legged tandem stance tasks. o One-legged stance tasks (left and right). All tasks were executed for 30 seconds and under three conditions: eyes open, eyes closed and on foam. Bigger amplitudes of the acceleration signal are associated with instability. Four different analyses of the raw anterior-posterior (A/P) and medio-lateral (M/L) signals were executed according to Moe-Nilssen.

Results: The 94 subjects devided over the 3 populations differ in weekly sport participation and do not differ in age, weight, length and body mass. The two sports and physical education groups had significantly smaller sway values during all standing tasks compared to the less sport experienced group for the conditions eyes open and on foam. During the eyes closed conditions no difference was found during standing.

Conclusions: The aim of study was to compare posture control during standing and walking for students with different athletic skills and sport experience and to select the most sensitive signal analysis, sensor direction, and test conditions. The 3 included populations differ in weekly sport participation and do not differ in age, weight, length and body mass. This study indicates that trunk accelerometry can discriminate for balance control during standing between healthy populations with different level of motor skill. No differences are found during normal eyes closed. Accelerometers are small, easy to use, and they can be used in almost every location and condition. There is only minimal influence on the awareness of the subject of the measuring process itself.

TP-38

Measuring trunk orientation with a CMOS camera: feasibility and accuracy

A. Gissot, G. Barbieri, M. Paindavoine and D. Pérennou

service de rééducation neurologique - CHU, Dijon, France

Introduction: The purpose of this study was to develop and validate a new tool to objectively quantify trunk orientation at the bedside, especially dedicated to the measurement of the lateropulsion in acute and subacute stroke patients.
Methods: We developed software to analyze 2D movement with a CMOS camera (Logitechâ Quickcam Pro 4000) and to calculate the orientation of a segment defined by 2 color markers. First, the accuracy, reproducibility and noise when measuring segment orientations were evaluated with the CMOS camera placed in different positions, and second trunk orientation was measured in static and in dynamic conditions both with a CMOS camera and with a gold standard 3D video system (BTS SMART-e).
Results: Results showed that the measurement was accurate (mean error = 0.05 ± 0.12°), reproducible (SD over 5 measurements = 0.005°) and steady (noise signal =0.02°). The data obtained with the CMOS camera were highly correlated with those obtained with the 3D video system both in static and in dynamic conditions. However, the CMOS camera must be relatively well centered on the measured segment to avoid error due to image distortion.
Conclusions: In conclusion, this could be an important step in the postural assessment of acute and subacute stroke patients. The CMOS camera, a simple, portable, compact, low cost, commercially available apparatus is the first tool to objectively quantify lateropulsion at the bedside. This method could also support the development of a rehabilitation program for trunk orientation based on biofeedback using the real time signal provided by the device.

TP-39

Movement analysis of quadruped gait in humans with and without chronic low back pain

H.M. Langevin[1], J.R. Fox[1], D. Stevens-Tuttle[1] and S.M. Henry[3]

[1]Neurology, University of Vermont, Burlington, VT, USA, [2]Orthopaedics and Rehabilitation, University of Vermont, Burlington, VT, USA and [3]Physical Therapy, University of Vermont, Burlington, VT, USA

Introduction: During quadruped gait, lateral side bending of the thoracic spine (toward the extended forelimb) and frontal plane tilting of the pelvis (toward the extended hindlimb) are coupled motions. We hypothesized that human subjects with chronic low back pain (cLBP) have decreased displacement of the spine and pelvis during quadruped gait, measurable as a decrease in the relative motion of thoracic and pelvic segments.
Methods: Seven subjects, 3 with cLBP of more than 6 months duration and 4 control subjects without LBP (No-LBP) were tested. None of the cLBP subjects were in an acute flareup or pain. Subjects performed quadruped walking in a straight line for 20 feet both at their own pace (3 trials) and at a standard speed (0.6 Hz, 3 trials), with each trial preceded by a 5 second stationary quadruped position recording. Thoracic and pelvic motion was recorded using two wireless orientation sensors (Microstrain, Inc) mounted over the middle of the sacrum (S1 level) and the spinous process of T10 respectively.
Results: Mean±SE peak intersegmental angle (degrees) was 21.8±3.7 for cLBP compared with 27.5±3.6 for No-LBP for self-paced trials and 21.4±4.5 vs. 27.5±3.5 for cLBP and No-LBP respectively for standard speed trials. No pain or discomfort was reported by cLBP subjects during or after testing. A similar decrease in thoraco-pelvic intersegmental motion was produced experimentally in a human subject during quadruped gait by restricting hip extension on one side with a leg strap connected to a chest harness (hobble). In a porcine motion restriction model in which three pigs wore such a hobble for 4 weeks and were then sacrificed, pronounced remodeling of the thoracolumbar fascia was grossly visible and could be quantified using ultrasound.
Conclusions: These preliminary results suggest that quadruped gait analysis may be a useful tool to examine movement patterns abnormalities in both humans with cLBP and animal models, in order to further our understanding of motor control and connective tissue pathology contributing to LBP.

TP-40

Neuroimaging of gait: an imagery approach

M. Bakker[1], F.P. de Lange[1], B.R. Bloem[2], R. Scheeringa[1] and I. Toni[1]

[1]FC Donders Centre for Cognitive Neuroimaging, Nijmegen, Netherlands, [2]Department of Neurology, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands and [3]Nijmegen Institute for Cognition and Information, Nijmegen, Netherlands

Introduction: One possible approach to gain further insights into the neurophysiology of gait involves the use of motor imagery. The rationale of this approach is that imagining a movement relies on neural processes similar to those used during real performance of the same movement. The objective of this study was to examine the effect of movement accuracy on cerebral activity and imagery time during motor imagery of gait.
Methods: Sixteen young right-handed subjects participated. We measured behavioural data and cerebral activity (event-related functional Magnetic Resonance Imaging (fMRI),3T) while subjects performed two tasks. During both tasks subjects faced photographs of walking trajectories. During one task (motor imagery: MI), subjects had to imagine walking along the walking trajectory. During the other task (visual imagery: VI), subjects had to imagine seeing a disc moving along the walking trajectory. We manipulated movement distance by changing the length of the walking trajectory, and movement difficulty by changing the width of the walking tra-

jectory. Subjects reported onset and offset of imagined movements with a button press. The time between the two button presses was taken as the imagery time (IT). Single-subjects estimates of fMRI effects for each TASK and PATH WIDTH were entered into a second-level Random Effects analysis, with inferences corrected for multiple comparisons at a cluster level ($p<0.05$).

Results: The effect of PATH WIDTH on IT and cerebral activity was different for the two tasks. During MI, a smaller PATH WIDTH resulted in longer IT, and increased activity bilaterally in the superior parietal lobule (Fig. 1). During VI, PATH WIDTH significantly influenced neither IT nor cerebral activity.

Conclusions: Subjects are influenced by accuracy constraint during MI, but not during VI. The increased accuracy required to walk along a narrow path increases imagery times and evokes increased activity along the dorsal visuomotor stream.

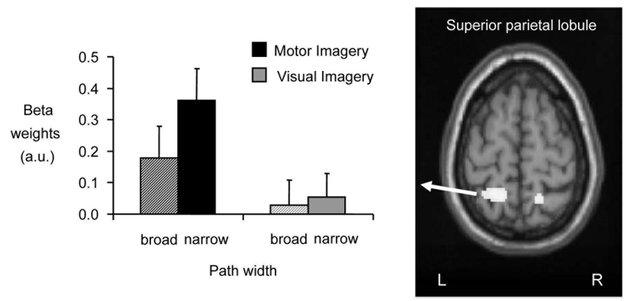


Figure 1. Effect of path width on cerebral activity during motor imagery of gait. Right: Anatomical map showing increased cerebral activity bilaterally in the superior parietal lobule during motor imagery along a narrow versus a broad path. Left: Effect of path width on cerebral activity in the left superior parietal lobule separately for both tasks.

TP-41

Correlation of postural alignment and equilibrium control in healthy young adults

E.A. Ferreira[1], A.P. Marques[1], M. Duarte[2] and E.P. Maldonado[2]

[1]School of Medicine, University of São Paulo, São Paulo, São Paulo, Brazil, [2]Laboratory of Biophysics, University of São Paulo, São Paulo, São Paulo, Brazil and [3]Physiotherapy, UNIFIEO, São Paulo, São Paulo, Brazil

Introduction: The maintenance of the equilibrium of the body as well as of the correct alignment of its segments are critical functions of the postural control system. At first glance one might expect that these two functions would be related, but the scarce data in literature suggests otherwise. Postural evaluation studies usually evaluate only one or two body segments in just one view. This study investigated much more thoroughly the relationship between postural alignment and equilibrium control in healthy young adults, quantitatively analyzing the position of multiple body segments in three views in a large sample (n=115).

Methods: 115 individuals were evaluated (75% female) with mean age of 26±7 years. The study took place in the Biophysics Laboratory at the University of São Paulo. After answering the anamnesis protocol and the consent term, polystyrene markers were placed on 86 specific anatomic points located on the head, trunk, upper and lower limbs. Three pictures (in anterior, posterior and sagittal views) were then taken and analysed with the free postural analysis software "SAPO" (http://sapo.incubadora.fapesp.br), specially developed to this study. The analysis of the pictures determined the X and Y coordinates of each anatomic point, from which angles and distances were calculated. In total, 23 variables were considered to evaluate the postural alignment. The postural control was investigated with a force platform through stabilographic analysis of the quiet standing. The area of displacement and the average velocity of the center of pressure were used to quantify the equilibrium control.

Results: The postural alignment of the sample was quantitatively evaluated using descriptive statistics for each of the 23 selected variables. Data suggest the existence of a similarity pattern for the postural alignment, but not one of symmetry in the frontal plane. There is an asymmetry trend between bilateral segments, with an inclination to the right of pelvis, shoulders and trunk in the anterior view. None of the postural alignment related variables presented any significant correlation with the selected postural control variables.

Conclusions: Postural evaluation, supported by the SAPO software, enabled a methodology for quantitative analysis of postural alignment. The proposed protocol also defined reference values for the positioning of different body segments. The results demonstrated no correlation between postural alignment and equilibrium control in healthy young adults, which supports previous studies. It is likely that the identified variability of the postural alignment measurements was inherent to the investigated phenomenon. This fact weakens the search for any statistical correlation between posture alignment and equilibrium control in healthy adults, but suggests others studies in individuals with disorders and significant asymmetries.

Neurophysiology of Sensorimotor Control 1

TP-42

Properties of the horizontal cervico-collic reflex in the squirrel monkey

J. Reynolds[1], D. Blum[3] and G. Gdowski[2]

[1]Biomedical Engineering, University of Rochester, Rochester, NY, USA, [2]Neurobiology and Anatomy, University of Rochester, Rochester, NY, USA and [3]Biomedical Engineering, Case Western Reserve University, Cleveland, OH, USA

Introduction: Daily activities such as walking evoke postural reflexes which can quickly accommodate for passive movements of the head and body in order to maintain balance. Neck reflexes are especially fast in order to prevent injury to the cervical spinal column due to rapid movements of the head on the trunk, such as whiplash caused by car collisions. The cervicocollic reflex (CCR) is a reflex of the neck which causes the muscles to contract when they are stretched. When the head is rotated about the trunk, the CCR

is thought to help stabilize the head with respect to the trunk by stretching primary spindle afferents which then activate a monosynaptic negative feedback pathway. This study is the first aimed at characterizing the reflex in non-human primates.
Methods: The CCR was evoked by sinusoidally rotating a squirrel monkey's trunk at varying frequencies and angular velocities along the C1-C2 joint while its head was held stationary in space. The torque exerted by the neck in response to trunk rotation results from the CCR and the neck's viscoelastic properties. Neck torque was averaged with respect to the stimulus frequency with torque gain computed as the ratio of torque magnitude and trunk-in-space velocity. In order to characterize the CCR alone, the viscoelastic properties were determined by repeating the experiment when the animal was anesthetized. The CCR was then computed as the difference between the alert and anesthetized recordings.
Results: Four squirrel monkeys were tested. In all monkeys, decreases in gain for both increasing velocity and increasing frequency were observed. The torque gain was, on average, 0.089 ± 0.054 oz*in/(°/sec) for 1 Hz stimuli. The average phase was $-69.00 \pm 10.45°$ with respect to the stimulus velocity at 1 Hz, thereby creating neck torques in phase with trunk position. In general, our results indicate that the CCR acts as a low-pass filter as a function of frequency. When the anesthetized results were subtracted from the alert recordings, the CCR maintained substantial torques at lower frequencies. However, at higher frequencies, the torque produced by the CCR was small and the viscoelastic properties of the neck became more dominant.
Conclusions: These results suggest that the CCR contributes significantly to reflexive stabilization of the head, particularly at lower frequencies.

TP-43

Influence of limb architecture on the force constraint strategy

C. Honeycutt[1] and T. Nichols[2]

[1]Biomedical Engineering, Georgia Institute of Technology, Atlanta, GA, USA and [2]Physiology, Emory University, Atlanta, GA, USA

Introduction: The postural response, characterized by Macpherson (1988) with horizontal platform perturbations, consists of exerted forces that cluster in two diagonally oriented directions. This 'force constraint strategy' has been shown to deteriorate and spread out as inter-paw distance is shortened. We propose that altered inter-paw spacing influences the direction of exerted muscular forces as well as the directional properties of muscle receptors that may influence exerted postural forces. These two factors may explain the dispersion of the force constraint strategy at shorter inter-paw distances. We have been developing the decerebrate cat preparation in order to investigate the contributions of sensory feedback and biomechanics on the postural response. Thus in order to understand how limb position might influence both the sensory and motor functions of muscles, we used intramuscular stimulation to estimate the exerted forces of individual muscles of the hindlimb.
Methods: We performed intramuscular stimulation (4 pulses at 200Hz over 20 ms) for 15 different muscles in the right hindlimb of precollicular decerebrate cats. We varied limb position and collected kinematic data.
Results: Preliminary data shows that the exerted forces of almost all muscles examined are sensitive to limb position suggesting a large role for biomechanics in force clustering changes. In addition, the exerted forces are typically directionally opposite to the EMG tuning curves derived from Macpherson (1988) and our data (Honeycutt 2005) potentially suggesting a link between length information and the postural response.
Conclusions: The change in exerted forces indicates that limb position and biomechanics play a significant role in the force clustering changes seen with different inter-paw spacings. However, limb position also has the potential to affect sensory information from muscle receptors. This would suggest a significant role for sensory feedback in the postural response. The decerebrate cat allows us the versatility to investigate all these conditions and thus is a good experimental model of the postural response.

TP-44

Deep brain stimulation does not improve automatic postural responses in Parkinson's disease

T.S. Phillips[1], P. Carlson-Kuhta[1], K.J. Van Ooteghem[2], A.R. Oates[2], J.S. Frank[3] and F.B. Horak[1]

[1]Neurological Sciences Institute, Oregon Health & Science University, Beaverton, OR, USA, [2]Department of Kinesiology, University of Waterloo, Waterloo, ON, Canada and [3]Faculty of Graduate Studies & Research, University of Windsor, Windsor, ON, Canada

Introduction: Deep brain stimulation (DBS) in either the subthalamic nucleus (STN) or the globus pallidus, internus (GPi) improves clinical symptoms of Parkinson's Disease (PD) such as rigidity, bradykinesia, and tremor. Since postural stability is the major cause for disability in patients with PD, our objective was to determine whether DBS also had a favorable outcome on automatic postural responses. Our previous studies showed that levodopa (L-dopa) medication did not improve automatic postural responses. Since DBS can also affect non-dopaminergic pathways, we hypothesized that DBS would improve postural responses.
Methods: We tested 17 subjects with PD who were randomized into bilateral DBS surgery in either STN or GPi and 16 age-matched healthy control subjects (CTR). The researchers were blinded to site of stimulation. All subjects were asked to maintain balance in response to a 9 cm forward surface translation at 15 cm/s. PD subjects were tested before deep brain stimulation surgery off (OFF) and on L-dopa (DOPA) and 6 months after DBS under 4 conditions: off both L-dopa and DBS (OFF), on L-dopa only (DOPA), on DBS only (DBS), on L-dopa and on DBS (BOTH). Backward peak center of mass (CoM) and peak center of pressure (CoP) were quantified and postural stability limits were defined as the difference between

peak CoP and peak CoM for non-step and non-fall trials. Prior to each condition, subjects' clinical motor signs were rated with the Unified Parkinson's Disease Rating Scale (UPDRS) Motor Subscale.

Results: PD subjects' postural stability limits under all conditions before and after surgery were smaller than CTRs, due to their smaller CoP and larger CoM displacements. After DBS surgery, postural stability limits were smaller in all conditions compared to before surgery. Before surgery, DOPA had no effect on stability limits but after surgery, stability limits were similar and larger in the DOPA, DBS and BOTH conditions than in the post-surgery OFF condition. Eleven subjects showed worse stability limits on BOTH compared to DOPA before surgery. Time to peak backward CoP was longer in PD than CTR and not affected by DOPA, DBS, or BOTH after surgery. The number of trials with steps and falls in response to surface translations was larger in PD than CTR and comparable before surgery in the OFF condition and in all 4 conditions after surgery, although DOPA reduced stepping before surgery. The UPDRS was similar for the BOTH (post-surgery) and DOPA (pre-surgery) conditions.

Conclusions: Despite consistent clinical motor scores, which primarily reflect self-initiated movements, DBS surgery does not improve feet-in-place automatic postural responses of PD subjects in response to backward disequilibrium. Worsening of postural responses after surgery could be due to a lesion effect of surgery, chronic DBS, or due to the normal progression of PD.

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TP-45

Robust muscle synergies simplify neural control of human postural responses

G. Torres-Oviedo and L.H. Ting

Biomedical Engineering, Emory University and Georgia Institute of Technology, Atlanta, GA, USA

Introduction: We hypothesized that the nervous system does not independently control muscles during complex, natural behaviors, but uses a few neural commands that activate preferred patterns of muscle coordination, called muscle synergies. In this study, we investigated the robustness of muscle synergies as a simplification strategy for postural control under several biomechanically distinct conditions.

Methods: Support surface translations in 12 horizontal plane directions were used to perturb nine healthy subjects standing in 6 different postural configurations: 1) one-legged, 2) narrow, 3) wide, 4) very wide, 5) crouched, and 6) natural stance (control condition). We analyzed spatial, temporal, and inter-trial variability in 16 leg and lower back muscles during quiet stance and during automatic postural responses in all postures. Non-negative matrix factorization was used to extract muscle synergies from the normal stance configuration and used to reconstruct muscle activation patterns at all other stance configurations.

Results: Six or fewer muscle synergies were required to reproduce the postural responses of each subject in the normal stance configuration. The composition and temporal activation of several muscle synergies identified across all subjects were consistent with the previously identified "ankle" and "hip" strategies in human postural responses. The same muscle synergies are also used in all of the experimental conditions, but they are recruited differently in each condition. Additional, task-specific synergies were used in one-legged and crouched stance. Moreover, inter-trial variability in muscle activation patterns was successfully reproduced by modulating muscle synergy activation levels. The composition and temporal activation of most of the muscle synergies were similar across subjects. Differences in muscle synergies across subjects represented subject-specific motor behaviors. For example, one subject bent his knees in response to all balance perturbation in all experimental conditions. This particular behavior was identified by a muscle synergy only used by this subject.

Conclusions: Our results suggest that trial-to-trial variations in the activation of individual muscles are correlated and represent variations in the amplitude of descending neural commands that activate individual muscle synergies. The robustness of synergy organization across postures suggests that muscle synergies represent a general simplification strategy underlying muscle coordination in standing postural control.

TP-46

"Warming-up" improves balance control in generalized myotonia patients

C. Horlings[2], G. Drost[1], K. de Laat[1], B.R. Bloem[1], B.G. van Engelen[1] and J.H. Allum[2]

[1]Neurology, Radboud University Medical Center, Nijmegen, Netherlands and [2]ORL, University Hospital, Basel, Switzerland

Introduction: Patients with generalized myotonia (Becker's disease) suffer from transient paresis of muscles, which diminishes with repetitive contractions (the so-called "warming-up" effect). Balance problems and falls are common in these patients, but have never been evaluated quantitatively.

Methods: Six patients with DNA proven generalized myotonia and 14 age- and sex-matched healthy controls performed 6 tasks: get up and go (with 3 meters walking); get up, walk around a chair and sit down again; tandem gait; standing on foam support with eyes closed; walking up and down stairs; and walking while rotating the head side to side. Balance control during these tasks was monitored using measurements of trunk pitch and roll at the level of the lower vertebral column (about L1-3) with angular velocity transducers. Tasks were randomly performed under two conditions: after a 10-minute rest period ("cold") and after repeating the task five times ("warmed up").

Results: Myotonia patients showed poorer balance control "cold" than "warmed up", as follows: during the "cold" condition, duration of every task was significantly greater; tandem gait showed significant increases in roll and pitch angles; and standing on foam showed a significant increase in pitch velocity. A trend for worsening of balance control was present for all other tasks. Balance in controls showed no differences between the two conditions. A comparison of myotonia patients under the "warmed up" condition with control data indicated that duration was no longer abnormal, but trunk sway remained abnormal for all tasks, except for standing on foam with eyes closed.

Conclusions: Balance deficits are present in generalized myotonia patients. "Warming-up" improves balance control, but not to the level of a healthy control. Measurements of trunk sway during balance tasks may be an adequate quantification technique to initially define myotonia and transient paresis in these patients, and may serve as an objective outcome measure to document the effects of symptomatic treatment.

TP-47

The effects of discrete, sequential, and reversal upper limb movements on seated postural control of the trunk

K.E. Pauhl, R. Chua and M.G. Carpenter

Human Kinetics, University of British Columbia, Vancouver, BC, Canada

Introduction: Anticipatory postural adjustments (APAs) to discrete arm movements are well defined in standing posture; however, research in the area of seated APAs have been inconclusive with support both for [1] and against [2] their presence while performing upper limb tasks. The present study examined whether APAs can be elicited in sitting postures, and if so, whether the APA activity is influenced by the complexity of the arm movement.

Methods: Five right handed participants (mean age ± SD = 25 ± 2 years), performed three bimanual upper limb tasks. Subjects were seated and secured to a modified chair without any foot or back support. Subjects' arms were initially relaxed hanging at their sides. In response to an auditory tone, subjects performed bilateral shoulder flexion as quickly as possible to a target positioned at shoulder height. Each of the following three tasks were performed in blocks of 15 trials: 1) discrete: move to target and hold for 3 sec; 2) sequential: move to the target pause for 3sec then return to starting position as quickly as possible; or 3) reversal: move to target and immediately return to the starting position as quickly as possible. Onset of trunk movement relative to arm movement was calculated from 3-D kinematic data. Onset of muscle activity in erector spinae (ES) relative to deltoid muscles was also calculated from surface electromyography (EMG).

Results: Evidence for seated APAs was observed in both kinematic and EMG measures in all subjects. Relative to arm movement initiation, backward trunk rotation was observed with a mean onset latency of 1.3±3.7ms across arm movement tasks. Anticipatory trunk movement was significantly earlier in the reversal compared to the discrete arm movement tasks ($p<0.05$). Similar observations were seen in EMG data. Onsets of ES activity occurred within the defined APA interval, and were earlier in the reversal compared to the discrete and sequential movement tasks.

Conclusions: We found APA activity to be present when participants performed seated voluntary arm movements. Furthermore, the timing of APA activity depended on the complexity of the upper limb task performed. The significance of determining the influence of movement type on APA activity becomes evident when this feature of postural control is examined in a population with balance disorders, such as Parkinson's disease. An increased understanding and awareness of how these movements influence postural muscle activity will aid in the development and implementation of improved rehabilitation programs in balance deficit populations. Acknowledgements: Parkinson 's Disease Foundation funding to KE Pauhl, and NSERC funding to MG Carpenter. References [1] Aruin, A., & Shiratori, T. Exp Brain Res (2003) 151: 46-53. [2] Van der Fits, IBM., Klip, AWJ., van Eykern, LA, & Hadders-Algra, M. Exp Brain Res (1998) 120: 202-216.

TP-48

Axial hypertonicity in Parkinson's disease: Abnormally distributed but unaffected by levodopa

W. Wright, V. Gurfinkel, L. King, P. Cordo and F. Horak

Neurological Sciences Institute, Oregon Health and Science University, Beaverton, OR, USA

Introduction: A classic symptom of Parkinson's disease (PD) is muscle hypertonicity, i.e. rigidity. Typically, rigidity is clinically assessed in the arms and legs, but control of posture and gait is thought to be affected by axial rigidity. Relatively little is known about rigidity of the body axis and specifically about quantifying and relating axial tone to functional impairment. We conducted a study to quantify axial rigidity in PD and to determine whether rigidity is reduced by levodopa treatment.

Methods: Axial rigidity was measured in 12 PD subjects and 13 age-matched controls by quantifying torsional resistance to twisting of the longitudinal axis at very low constant angular velocity (1°/s). Specifically, the feet were rotated relative to the fixed pelvis (hip tone) or the feet and pelvis were rotated relative to fixed shoulders (trunk tone). Rotation followed a saw-toothed pattern for 3-5 cycles at an amplitude of 10° clockwise (CW) and counter-clockwise (CC). Very low acceleration at starts and stops ($<12°/s^2$), together with the low velocity rotation was meant to virtually eliminate phasic sensorimotor responses, thus assessing only tonic activity. The set-up required subjects to maintain standing equilibrium and fixed body parts could not be used as a spatial reference because fixed parts were free to translate, but not rotate.

Results: The ratio of hip-to-trunk torque was significantly greater in PD subjects than controls ($p<0.05$), and this distribution was unchanged by levodopa ($p=0.28$, n.s.). PD subjects OFF-medication had significantly higher axial rigidity ($p<0.05$) in both the hips (5.07 Nm) and trunk (5.30 Nm) relative to age-matched controls (3.51 Nm and 4.46 Nm, respectively). Levodopa had no effect on axial hypertonicity ($p>0.10$), which remained significantly higher in PD subjects ON-medication relative to controls ($p<0.05$; Hip = 4.93 Nm and Trunk = 5.11 Nm). A significant correlation ($r=0.73$, $p<0.05$) was found between UPDRS scores and hip rigidity for PD subjects OFF-meds. Torsional resistance to CW versus CC axial rotation was found to be more asymmetrical in both the hips and trunk in PD subjects relative to controls, however, no correspondence between the direction of axial asymmetry and the side of disease onset was found.

Conclusions: Axial hypertonicity and its segmental distribution and asymmetry could underlie functional impairments of posture and locomotion found in PD, which is supported by the correlation of hip rigidity with clinical measures. The absence of a levodopa effect supports the hypothesis that axial tone is controlled by separate circuits from muscle tone in the extremities.

TP-49

Increasing stance width compensates for perceived degradation in balance during pregnancy

J. Jang[1], K.T. Hsiao[2] and E.T. Hsiao-Wecksler[1]

[1]Department of Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA and [2]Department of Obstetrics and Gynecology, California Pacific Medical Center, San Francisco, CA, USA

Introduction: Pregnant women often remark that their balance degrades during pregnancy. One in four pregnant women are likely to experience a fall (Dunning, Am J Ind Med 44(6), 2003). Prior studies have examined the gravida's physical posture changes to address ergonomic issues (Gilleard, Arch Phys Med Rehabil 83(12), 2002) or balance changes due to analgesics in laboring women (Davies, Anesthesiology 97(6), 2002). No studies, however, have measured changes in balance throughout pregnancy or after delivery; therefore, we conducted a prospective study to assess standing balance from the 2nd trimester through 6-months postpartum.
Methods: Fifteen pregnant (PG) and 15 nonpregnant control (CG) subjects were recruited. Each session consisted of ten 30s trials of open-eyes quiet standing using preferred stance width. Center of pressure data from a large forceplate (BP600900, AMTI) were used for balance measures based on traditional summary statistic and newer stochastic-diffusion techniques. Traditional parameters (Rocchi, Med Biol Eng Comput 42(1), 2004) included Angular Deviation from the anterioposterior (AP) axis; and AP, mediolateral (ML), and radial (RAD) components of Displacement Standard Deviation (SD), Mean Sway Velocity (Vel), and 95% Total Power Frequency. Stabiliogram diffusion analysis parameters (Collins, Exp Brain Res 95(2), 1993) included Short and Long term Diffusion Coefficients (DS, DL) and Scaling Exponents (HS, HL) for three directions. Preferred stance width (SW) was also measured. Subjects rated perceived sense of balance (SB) on a Likert scale (0:normal-10:extremely unstable). Fourteen PG and 11 CG completed all testing at 4-week intervals from pregnancy week 16 until delivery, and 6 & 12 weeks and 6 months postpartum. Mixed-models repeated-measures ANOVA were used to test for Group and Time effects over weeks 16-64. Also, PG were analyzed using RM ANOVA for Time effects before-delivery (weeks 16-36), and paired t-test to examine pre-post delivery differences, i.e., 3rd trimester (weeks 28-36) and postpartum (weeks 46-64). Adjusted significance level was 0.002.
Results: Significant Group×Time interactions were found for SW and SB ($p<0.001$). PG increased stance width during pregnancy (~4 cm), which returned after delivery ($p<0.001$), and increased perceived balance scores from 1.7 to 4.7 (average), which dropped to 1.1 ($p=0.004$). PG had larger SD_AP, SD_RAD, DL_AP, and DL_RAD than CG ($p\leq0.001$), indicating pregnant subjects generally had greater postural sway and reduced closed-loop stability, especially in the AP direction, throughout the sampling time. While these parameters increased slightly during pregnancy and dropped after delivery, these changes had borderline significance ($0.01\leq p\leq0.03$). No significant changes were noted for CG for weeks 16-64 ($p>0.05$).
Conclusions: Pregnant women perceive that balance degrades; however standing balance measures suggest little change over time. Increasing stance width may be used to compensate for actual or perceived balance changes.

TP-50

Repeated quiet-stance stabilometric balance testing over a 15-month period

J. Jang and E.T. Hsiao-Wecksler

Mechanical Science and Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA

Introduction: It is generally assumed that, at least in young healthy adults, balance capacities do not change significantly over an extended time period. Accurately assessing balance over that period is another story. Analyses of postural sway during quiet standing are often used to quantify balance. Planar representation of postural sway is often called a stabilogram. Several papers have discussed repeatability and learning effects during stabilometric testing of postural sway in undisturbed quiet stance over multiple testing sessions (e.g., Elliott, Physiol Meas 19(2), 1998; Nordahl, Aviat Space Environ Med 71(9), 2000). These studies have found mixed results, either suggesting that measures vary from early to later sessions (Holliday, Agressologie 20(4), 1979) or no variations occur with repeat testing (Black, Am J Otolaryngol 3(5), 1982; Takala, Clin Biomech 12(7), 1997). In this paper, we present results from a control group cohort used in a 15-month prospective study of standing balance measures in pregnant women.
Methods: Fifteen female subjects (31.2 ± 4.3 yrs) were recruited and 11 completed all testing sessions (i.e., 4-week intervals for 40 weeks and then at weeks 46, 52, and 64). Each session consisted of ten 30s trials of open-eyes, unshod quiet standing. Subjects were allowed to chose a preferred stance width (SW) at each session. Center of pressure data from a large forceplate (BP600900, AMTI) were used for averaged balance measures based on traditional summary statistic and newer stochastic-diffusion techniques. Traditional parameters (Rocchi, Med Biol Eng Comput 42(1), 2004) included Angular Deviation from the anterioposterior (AP) axis; and AP, mediolateral (ML), and radial (RAD) components of Displacement Standard Deviation (SD), Mean Sway Velocity (Vel), and 95% Total Power Frequency. Stabiliogram diffusion analysis parameters (Collins, Exp Brain Res 95(2), 1993) included Short and Long term Diffusion Coefficients (DS, DL) and Scaling Exponents (HS, HL) for three directions. Time effects over the 14 sessions were tested with repeated-measures ANOVA.
Results: Over the 15 months, no statistical differences were noted (based on adjusted significance level of 0.002); however, borderline significant results were found for SD (AP, ML, and RAD) and Vel (ML), $0.005 \leq p \leq 0.047$. These parameters were found to decrease and remain relatively consistent after the first session; these borderline results were mitigated by eliminating week 0 from the RM ANOVA ($p > 0.12$). Average stance width was found to increase after week 0 by ~2cm, although not significantly ($p=0.46$). SW was also found to correlate strongly with these balance parameters (Pearson correlation: $0.017 \leq p \leq 0.043$).
Conclusions: Providing support for repeated testing assumptions, stabilogram balance measures appear to not vary significantly over long time periods in young healthy women. Variation in some measures after the first session may be due to

learning effects, although change in stance width may also be a factor.

TP-51

Obstacle avoidance in HMSN 1a patients is impaired and requires more cognitive control than in healthy controls

M. van der Linden[1], A. Queralt[2], V. Weerdesteyn[1], H.T. Hendricks[1] and J. Duysens[3]

[1]Rehabilitation Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [2]Escola Universitària d'Infermeria and Facultat de Ciències de l'Actividad Física i l'Esport, Universitat de València, València, Spain, [3]SMK-RDE, Maartenskliniek, Nijmegen, Netherlands and [4]Neurology, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands

Introduction: Gait and mobility related problems frequently occur within patients with hereditary motor and sensory neuropathy type 1a (HMSN 1a), although they are often regarded as non- or only mildly disabled (Van der Linden et al., in press). These ambulatory problems often include falls and sprains due to stumbling and tripping. Disease-related factors that are potentially contributing to this problem are decreased sensory feedback, reduced nerve conduction velocities, and reduced distal muscle strength, which may impair their corrective responses. As a compensatory mechanism, these patients may rely more heavily on cognitive control of balance and gait. In order to gain more insight into this topic, we investigated the ability of mildly affected HMSN 1a patients to successfully avoid obstacles during walking, both as a single task and while simultaneously performing a cognitive task.
Methods: Eleven well ambulant HMSN 1a patients participated in the study. All patients were able to walk barefooted and unassisted for more than one hour. In addition, 11 healthy age-matched controls were selected. The participants walked on a treadmill at a speed of 3 km/h. An obstacle fell unexpectedly in front of their left leg during 3 phases of the step cycle (late stance, early swing and mid swing). Trials were easiest in the late stance and most difficult in the mid swing condition, because the time available to respond to the obstacle decreased when the obstacle was dropped at a later phase of the step cycle. The participants had to avoid 30 obstacles under normal conditions (single task) and 30 obstacles while simultaneously performing a cognitive task (dual task).Avoidance strategies (short or long step) and failure rates were collected.
Results: The avoidance strategies of the HMSN 1a patients and healthy subjects were similar. In contrast, the overall failure rates of the HMSN 1a patients (18.5%) were significantly higher compared to the healthy subjects (9.3%) in the single task condition. The group difference was most pronounced in the mid swing trials (26.7% vs 12.9%). In the dual task condition, the failure rates of the HMSN 1a patients increased to 33.3% in these mid swing trials, whereas no significant increase was observed in the controls (12.3 %).
Conclusions: These results indicate that HMSN 1a patients have a decreased ability to avoid suddenly appearing obstacles during walking, probably as a result of delayed and less efficient responses. When the patients' attention was divided, the failure rates increased. This indicates that obstacle avoidance in HMSN 1a patients indeed demands more cognitive control. As in every day life people frequently encounter distracters while walking, the increased cognitive dependency may place HMSN 1a patients at increased risk for falling.

TP-52

Responses to stepping on an unexpectedly lowered support surface in HMSN 1a patients in comparison with control subjects

M. van der Linden[1], D. de Kam[1], H.T. Hendricks[1], B.G. van Engelen[2] and J. Duysens[3]

[1]Rehabilitation Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [2]Neurology, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands and [3]SMK-RDE, Maartenskliniek, Nijmegen, Netherlands

Introduction: Hereditary Motor and Sensory Neuropathy type 1a (HMSN 1a) is characterized by distal motor and sensory loss. The contribution of these features to the observed balance and gait problems remains largely unknown. This study investigated muscle responses to an unexpected step-down in HMSN 1a patients, compared to healthy subjects. Furthermore the relationship between muscle responses and clinical symptoms was studied.
Methods: Experiments were performed on a walkway that embedded a platform that could be unexpectedly lowered 5.0 cm before foot contact. Glasses blocked the lower part of the visual field. Surface electromyographic data was collected from 11 HMSN 1a and 11 healthy adults of similar age. In a clinical evaluation, the patients' muscle force (MRC), vibration threshold (Reidel-Seiffer tuning fork) and surface sensation (monofilaments) were measured. All HMSN 1a patients were able to walk barefooted and unassisted for more than one hour and therefore represent a group of relatively mildly disabled patients.
Results: The absence of expected heel contact triggered responses in the ipsilateral anti-gravity (MGi, RFi, BFi) and contralateral flexor muscles (TAc, BFc) in both HMSN 1a patients and healthy subjects. This specific motor pattern was presumably activated to arrest the forward propulsion of the body. The onset latencies of the MGi, TAc, BFc muscles were significantly delayed in the HMSN 1a patients compared to the controls (64-88 ms vs 38-52 ms). The amplitude of the responses in HMSN 1a patients was also reduced as compared to controls. The degree of distal sensory and motor loss showed significant correlations with the onset latency and amplitude of the response.
Conclusions: It can be concluded that the absence of expected foot contact triggered a fast braking reaction that was deficient in HMSN 1a patients. Furthermore, their response reduction was proportional to their sensory and motor impairments. The delayed reaction onset and reduced amplitude induced substantial disturbances of equilibrium, even causing loss of balance while this was never observed in the controls. This instability might contribute to falls in these patients in daily life.

TP-53

Is the hip joint a major player in locomotor trajectory adaptation?

M. Hong, C. Wong and G.M. Earhart

Program in Physical Therapy, Washington University School of Medicine, St. Louis, MO, USA

Introduction: The podokinetic (PK) system is the somatosensory-motor system responsible for directional control of locomotor trajectory through foot contact with the floor. After adapting to PK stimulation, i.e. walking on a rotating treadmill, people demonstrate an after effect termed podokinetic after-rotation (PKAR) and inadvertently turn when asked to walk in place without vision. This adaptation is mediated by numerous sources. The purpose of this study was to specifically examine the importance of hip joint afferents in this process.

Methods: Thirteen young healthy volunteers (8 women), between the ages of 19 and 33, stepped on a rotating treadmill maintaining a fixed orientation in space under two testing conditions: 1) in a standing position or 2) in kneeling (kneel-stepping), making the hip joint a major contributor of afferent information. The treadmill rotated in the clockwise direction at 60 deg/sec and PK stimulation consisted of subjects stepping on the rotating treadmill in three 5-minute intervals, separated by three 5-minute rests. The two testing conditions were separated by at least 24 hours in order to eliminate the possibility of the after-effect carrying over from the first session. After PK stimulation, the subjects stepped in place on a stationary surface for 10 minutes. The subjects were blindfolded and asked to step to a metronome in order to control for cadence. Kinematic data were recorded during PK stimulation phase and during PKAR using a 3-D motion capture system (Motion Analysis Corporation, Santa Rosa, CA). Data collected during PK stimulation were used to determine the amount of hip yaw rotation for each session. With data obtained during PKAR, we took the first derivative of trunk position in space to calculate trunk angular velocity for each subject. We used paired t-tests to compare hip yaw rotation and trunk initial and maximum angular velocities across conditions.

Results: During PK stimulation, group mean hip rotation was 12.2 $\pm$ 2.59 deg (mean $\pm$ SD) during stepping and 18.69 $\pm$ 3.57 deg during kneel-stepping ($p<0.05$). Group mean initial and maximum velocities were significantly higher in PKAR following stepping on the rotating treadmill than those following kneel-stepping ($p<0.05$).

Conclusions: Our data suggest that the hip joint is not the major contributor to adaptation of locomotor trajectory, although it plays a part in the process. This is supported by the fact that kneel-stepping resulted in slower initial and maximum velocities during PKAR despite the use of greater hip yaw rotation in the adaptation phase. Afferent inputs from the knee, ankle or plantar surface of the foot may have crucial roles in this adaptation. Further studies need to examine different sources of inputs in isolation in order to determine the key contributors involved in adaptation of locomotor trajectory.

TP-54

The nature of the "first trial reaction" in balance control

L.B. Oude Nijhuis[1], J.H. Allum[2], M.G. Carpenter[3], G.F. Borm[4] and B.R. Bloem[1]

[1]Neurology, Radboud University Nijmegen Medical Center, Nijmegen, Netherlands, [2]ORL, University Hospital, Basel, Switzerland, [3]School of Human Kinetics, University of British Columbia, Vancouver, BC, Canada and [4]Epidemiology and Biostatistics, Radboud University Nijmegen, Nijmegen, Netherlands

Introduction: In posturography experiments, the behavior of postural reactions to the very first balance disturbance is typically different from those evoked by the ensuing ones. Therefore, the "first trial reaction" is usually excluded from the analyses, leaving the average "habituated" response to a series of successive stimuli, to study the adapted responses. This method may be questioned because everyday falls are typically a one-time event. Hence, the first trial is possibly most relevant in order to study balance reactions associated with actual falling. We therefore investigated the first trial reaction and compared it to subsequent trials.

Methods: We instructed 36 healthy subjects (mean age 23 years; 18 men) to maintain their balance while standing on a rotating support-surface. Subjects were perturbed in 6 different directions, with 10 consecutive identical trials for each perturbation direction. We used a Latin-square design to counterbalance the order of these sequences across subjects. Full body kinematics and electromyographic responses from 10 muscles were recorded.

Results: Mixed model analysis revealed that the displacement of the center of mass (CoM) was 5 to 15 % greater for the very first postural perturbation, compared to the responses during the subsequent 9 identical trials. Furthermore, the first trial reaction was present whenever a new sequence of perturbations was introduced. The reaction was however 9% greater in the very first sequence of 10 perturbations compared to subsequent sequences ($P< 0.01$). First trial reactions to backward perturbations showed the greatest effects, and these differed significantly from lateral perturbations of the platform. For backward perturbations, differences between first and second trials were greatest in ankle, trunk and arm segments. These changes could be related to higher activity in tibialis anterior, external oblique and deltoid medium muscles.

Conclusions: The first trial reaction has to be taken into account when investigating balance control. The effect being greatest in pitch directions suggests that different physiological mechanisms are involved for balance control in the pitch and roll directions.

TP-55

The effect of arm swing on the lower limb during gait

J. Stephenson, S.J. De Serres and A. Lamontagne

School of Physical and Occupational Therapy, Faculty of Medicine, McGill University, Jewish Rehabilitation Hospital, Site of CRIR, Montreal, QC, Canada

Introduction: Human walking involves coordinated movements of all four limbs, with a velocity dependent coordination pattern observed between the upper and lower limbs. The muscular activation underlying these movements is generated via functional networks of neurones located within the spinal cord (CPGs), and there is evidence for the existence of excitatory neural pathways connecting the motoneurones of upper and lower limbs. As such, we hypothesised that arm swing during gait has the potential to influence lower limb muscle activation. This study examined the effect of arm swing on lower limb muscle activation patterns during walking.

Methods: Healthy subjects (N=4) walked on a treadmill at their comfortable speed, under three conditions: (1) Holding onto fixed handles that prevented arm movements; (2) Holding onto low-friction sliding handles that permitted arm movements; and (3) Not holding on to handles. During the latter two conditions subjects were instructed to swing their arms while they walked.

Surface electromyography (Noraxon TeleMyo 900) was recorded bilaterally from upper limb (posterior deltoid; anterior deltoid; latissimus dorsi; biceps brachii) and lower limb (soleus; tibialis anterior; semitendinosus; rectus femoris) muscles. Three-dimensional full-body kinematics were recorded using a ten-camera VICON system.
Results: Despite different upper limb kinematic profiles across conditions, patterns of upper limb muscle activity were comparable. There was a trend for reduced tibialis anterior activation in early stance (controlling toe down; 0-20% of the gait cycle) and early swing (toe clearance; 60-80% of the gait cycle) when arm swing was prevented.
Conclusions: Similar upper limb muscle activation across conditions supports the concept that CPGs underlie rhythmic movement. Differences in lower limb muscle activation across conditions support the existence of a neuronal linkage between upper and lower limb motoneurones. This information may have important implications for gait rehabilitation, where patients are commonly trained on a treadmill with stationary handrails. Supported by CIHR, REPAR-MENTOR and McGill Faculty of Medicine Scholarships.

TP-56

Trunk muscle activation in the control of upright balance following multi-directional support surface translation

R. Preuss[1] and J. Fung[1]

[1]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [2]CRIR Research Centre, Jewish Rehabilitation Hospital, Laval, QC, Canada

Introduction: Research on postural control has traditionally focused on the lower limbs, often treating the trunk as a single, rigid segment. In reality, the trunk represents a complex multi-articular body, and as such requires a finely tuned coordination between its multiple kinematic degrees of freedom that can only be achieved via neuromuscular coupling. The present study was conducted to examine the role of the trunk musculature in regaining equilibrium from perturbations.
Methods: The EMG activity in 14 trunk muscles, and 2 hip muscles, was examined following multidirectional horizontal surface translations (4 randomly ordered trials in each of 8 directions) in 13 healthy subjects, in both standing and sitting. Trunk motions in 3D were captured by a 6-camera Vicon system and analyzed with a 4-segment model consisting of pelvic, lumbar, upper and lower thoracic segments. The effects due to initial posture and surface perturbation direction on the neuromuscular response in the trunk were investigated with 2-way ANOVAs conducted on the integrated EMG signals over the first two 250ms intervals following perturbation onset. The degree of interdependence in the acquired EMG signals, inferring neuromuscular coupling, was examined using principal component analysis (PCA), over the initial 500ms. Finally, to investigate if a fixed spatiotemporal relationship existed in the activation patterns of the different trunk muscles, cluster analysis was performed on the individual muscle loadings from the previous PCA.
Results: Both the direction of surface translation and the test posture were found to significantly affect the EMG response amplitude, with an interaction effect often present. These effects, however, were largely explained by differences in the initial trunk kinematics under the different test conditions, such that trunk muscle activation was closely related to the actual trunk displacements. A high degree of neuromuscular coupling was also observed in both test postures, with most of the EMG variance (>80%) accounted for by 2 principal components, under all test conditions. Despite this coupling, no consistent muscle groupings were identified across the subject population, and the groupings identified for the individual subjects accounted for less than half of the muscles studied.
Conclusions: Our results suggest that trunk muscle activation in the control of upright balance is specific to the actual perturbation experienced by the trunk, and is highly coordinated across all trunk levels. The individual muscle activation patterns, however, did not group in any consistent manner with respect to their spatiotemporal characteristics, suggesting that explicit activation of muscle synergies by the CNS is unlikely to explain the observed EMG patterns. Modulation of trunk impedance via feedback driven inter-muscular spinal pathways, however, may provide a more plausible explanation for the observed neuromuscular coordination.

TP-57

Modality-specific feedback affects gait synchronization during side-by-side walking

Y. Galil[2], I. Tamir[2], A. Zivotofsky[3], L. Gruendlinger[1], R. Bartsch[3], M. Plotnik[1] and J.M. Hausdorff[1]

[1]Laboratory for Gait & Neurodynamics, Movement Disorders Unit, Tel-Aviv Sourasky Medical Center, Tel-Aviv, Israel, [2]Depts. of Physical Therapy and Biomedical Engineering, Tel-Aviv University, Tel-Aviv, Israel, [3]Bar-Ilan University, Ramat-Gan, Israel and [4]Division on Aging, Harvard Medical School, Boston, MA, USA

Introduction: Entrainment of gait rhythm to external cues has been studied in healthy adults and various patient groups. Walking while holding a partner's hand may also entrain gait. However, the sensory modalities mediating gait synchronization between two side-by-side walkers have not been studied quantitatively.
Methods: 14 pairs of height- and gender-matched healthy young adults (age 26±2 yrs) walked together five times along a straight 70m path, each time with different sensory feedback, in a random order. Visual feedback (VF) was eliminated using side blinders, auditory feedback (AF) was eliminated using earphones supplying white noise, and tactile feedback (TF) was provided by handholding. Subjects walked once with all three modes of feedback provided (3F), once without any of them (0F), and once with each kind of feedback provided without the other two. Trunk-mounted accelerometer data were recorded and low-pass filtered. Acceleration in earth vertical axis was used for estimating mean stride time, asymmetry of the cadences of the two walkers, and the mutual gait synchronization index (GSI), quantifying synchronization on a scale of 0-1 using the phase-synchronization method. A GSI reference value was obtained by computing the index with "crossed" signals from different walks.
Results: The average GSI was 0.24±0.22 in the 3F condition, 0.18±0.18, 0.15±0.15 and 0.06±0.09 in the TF, AF and VF conditions, respectively, 0.16±0.19 in the 0F condition and 0.06±0.04

for the no-synch reference. GSI was significantly higher for the 3F condition in comparison to all other conditions ($p<0.02$) except for the TF condition ($p=0.10$). VF condition produced the lowest synchronization levels, indistinguishable from the no-synch reference. Further inspection revealed that the distribution of the GSI was bimodal and walks were thus classified as either "synchrnonized" or "non-synchronized". 7 pairs showed synchronized walking in at least one condition and 7 others showed no synchronization in any condition. Synchronized walking was always observed concurrently with tightly matched cadences. The synchronized pairs did not differ from the non-synchronized ones in age, height or height asymmetry, but had a longer stride time in all walks, except for the VF condition, (e.g. 1.14 ± 0.04 sec vs. 1.07 ± 0.08 sec in the 3F condition; $p<0.02$).
Conclusions: This study is the first to use quantitative methods to measure gait synchronization during side-by-side walking. Both auditory and tactile feedbacks were effective means of synchronizing gait, but visual feedback alone was not. Auditory feedback may work by sensing and acting on discrete rhythmic events, e.g., heel strikes, and handholding may synchronize gait via upper limb coupling. The reasons why visual feedback is ineffective and why better inter-subject gait synchronization is associated with lower gait cadence are unclear. Potential clinical implications remain to be more fully determined.

TP-58

Postural control in multiple sclerosis during reach and lean perturbations

J.G. Remelius[1], L.H. Chung[1], M.B. Johnson[1], B. Smith[2], G. Baquis[2] and R. Van Emmerik[1]

[1]Department of Kinesiology, University of Massachusetts, Amherst, MA, USA and [2]Department of Neurology, Bay State Medical Center, Springfield, MA, USA

Introduction: While postural control is a common problem in people with Multiple Sclerosis (MS), the factors contributing to postural instability remain unclear. Further, symptomatic fatigue is a primary symptom in ~70% of people with MS, thus a quantification of the relationship between postural stability and fatigue is important. The purpose of this study was to determine the influences of MS and fatigue on variability and velocity in center of pressure (COP) and center of gravity (COG) during postural perturbations.
Methods: Ground reaction forces and 3-D kinematics were measured in 12 women with MS (age 55.6 ± 9.7 years) and 12 non-MS women (age 53 ± 9.2 years) for 15 seconds under different postural perturbation conditions. Kinematic and kinetic data were collected with the Qualisys motion capture system (35 retro-reflective markers) and two AMTI force plates. Experimental conditions included: forward lean and reach, backward lean, and lateral lean and reach. The trials were sorted into sagittal plane movements or frontal plane movements. Symptomatic fatigue was quantified with a Visual Analog Fatigue Scale (VAFS). Women with MS were tested under low ($VAFS = 3.8 \pm 2.1$) and moderate ($VAFS = 5.6 \pm 2.0$) fatigue, induced by participation in a strength testing protocol. Non-MS women were tested under low levels of fatigue (1.2 ± 0.9 vs. MS). Expanded Disability Status Scale (EDSS) scores in the MS group ranged from 2.0 to 6.0 (median = 4.0), indicating mild to moderate impairment. Postural control was quantified by standard deviation in anterior-posterior (A/P) and medio-lateral (M/L) directions and mean net velocity of the COP and COG motion. Statistical differences were examined by ANOVA with a criterion alpha level of $p<0.05$, and Tukey's HSD was used post hoc for pair wise comparisons.
Results: Mean COP variability was significantly greater in women with MS in both the frontal and sagittal plane trials compared with non-MS women. Mean COG variability was significantly greater in the women with MS compared with the non-MS women for the frontal but not the sagittal plane trials. Mean COG variability was significantly greater in the women with MS compared with the non-MS women. COP and COG velocity were significantly greater in the women with MS compared with the non-MS women in both planes. During lean and reach trials, COP and COG migrated significantly further in the lean direction for non-MS women than the women with MS. There were no significant differences between the fatigue and non-fatigue test conditions for the women with MS.
Conclusions: The greater COP and COG variability and velocity in the women with MS indicate changes in balance control compared to non-MS women when upright balance is perturbed. These alterations in static balance control appear to be independent of differences in symptomatic fatigue. Support: PP0934; National Multiple Sclerosis Society

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TP-59

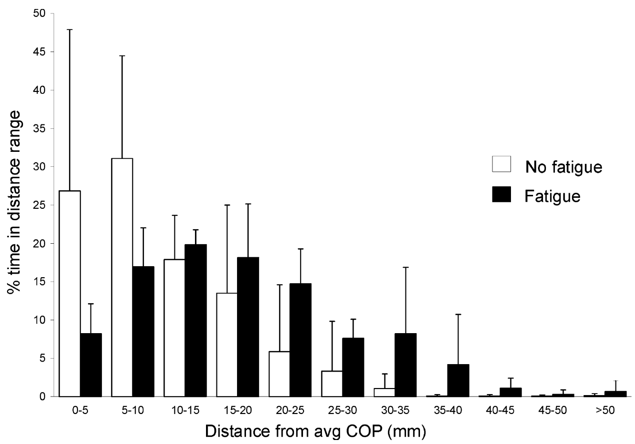
Upper limb repetitive motion-induced fatigue affects both the posture and movement task characteristics

J.R. Fuller[1], K.V. Lomond[1] and J.N. Cote[2]

[1]Kinesiology and Physical Education, McGill University, Montreal, QC, Canada and [2]Pain, Mind and Performance Research Unit, Jewish Rehabilitation Hospital (CRIR site), Laval, QC, Canada

Introduction: Upper limb repetitive motions are a regular occurrence in everyday life and in occupational settings. Recent work has shown that repetitive motion-induced fatigue not only impairs the arm motion characteristics but also provokes complex reorganization across the body, most notably with increased trunk motion. This could either reflect altered postural stability or a voluntary strategy to contribute to the arm task. To elucidate this question, we assessed the effects of upper limb repetitive motion-induced fatigue on posture and movement characteristics during a repetitive reaching task.
Methods: Healthy subjects ($n = 4$) stood and performed the task with the dominant arm moving to either of two targets placed at shoulder height, at 25 and 100% of arm's length, in front of the subject's midline. They executed one reach/s until they scored 8 on a Borg CR-10 scale or the movement frequency could not be maintained. Towards the end of every minute, we recorded the activity of 16 muscles (Noraxon©), whole body kinematics (VICON-Peak©) and forces under the feet (AMTI©). The effect of fatigue on the ability to stabilize posture while performing the arm task was assessed every minute by applying one forward support surface translation of 8 cm in 0.4 s (peak acceleration = 2.5 m/s^2). Heart rate was recorded continuously (Polar©).
Results: The average time to fatigue was 6m45s ± 1m30s. Mean heart rate was not altered by fatigue. When fatigued, subjects' COP was located further away from their average COP for a greater amount of time (fig. 1). COP displacement was increased in the medio-lateral direction in all subjects and in the antero-posterior

direction in most subjects. With fatigue, the center of mass (COM) was displaced upward and forward, and the peak endpoint mediolateral excursion was deviated laterally towards the dominant side. **Conclusions:** Our findings suggest that postural stability and movement characteristics may be impaired by repetitive motion-induced fatigue. Analysis of postural stabilization strategies will further elucidate the mechanisms underlying posture-movement reorganization patterns following global fatigue.



TP-60

Noise-enhanced dynamic balance control during sit-to-stand

B.L. Patritti[1], M. Schmid[2], P.K. Kasi[1], A. Mirelman[1], S.E. D'Andrea[3] and P. Bonato[4]

[1]Department of Physical Medicine and Rehabilitation, Harvard Medical School - Spaulding Rehabilitation Hospital, Boston, MA, USA, [2]Department of Applied Electronics, University Roma Tre, Roma, Italy, [3]Afferent Corporation, Providence, RI, USA and [4]The Harvard-MIT Division of Health, Sciences and Technology, Cambridge, MA, USA

Introduction: The transfer from sitting to standing is a common activity of daily living requiring dynamic balance control. In older adults impaired balance due to diminished somatosensation may be a factor in the risk of falling during sit-to-stand (STS). Recently, it has been shown that sub-sensory mechanical noise applied to the soles of the feet can improve quiet standing balance control in healthy older adults and adults with disease-related sensory loss via a mechanism known as stochastic resonance (Priplata et al., 2006). The aim of this study was to demonstrate whether input noise to the feet can also be used to enhance dynamic balance control of older adults while performing STS. **Methods:** Nine older adults (mean age = 72 yrs) with a self-reported history of instability performed 10 STS trials at a self-selected speed while wearing vibrating sports sandals. Sub-sensory mechanical noise was applied to the soles of the feet via tactors embedded in the midsoles of the sandals. Sensory thresholds to the noise stimulus were set for each foot in sitting and standing postures. The stimulation level during testing was set to 90% of the thresholds and increased from the sitting to standing level using footswitches on the sandals. The noise stimulus was presented using a double blind design, with 5 trials performed without stimulation (control) and 5 trials with stimulation (noise) ordered in a pairwise randomized manner. STS phases were determined from whole body kinematics and external forces under each foot recorded during each trial. Dynamic balance control was characterized by the difference between the centre of mass (CoM) and the centre of pressure (CoP) trajectories (Corriveau et al., 2001). Two-tailed paired t-tests were used to test group mean differences between CoM-CoP parameters for the control and noise conditions.
Results: Mean resultant CoM-CoP parameters (distance and RMS difference) at seat-off (Fig 1A) and during the standing-up phase after seat-off (Figs 1B, 1C) showed significant decreases for the noise condition compared to the control condition. The tighter coupling between the CoM and CoP trajectories indicates dynamic balance control was improved for the noise condition. The input noise likely enhances the somatosensory feedback of small pressure changes under the feet. This leads to a better sense of foot position, and improved control of the body CoM trajectory over the base of support of the feet (i.e. CoP) while transferring from seat-off to standing.
Conclusions: These results suggest noise-based devices such as randomly vibrating shoe insoles could improve dynamic balance control during activities of daily living such as STS.

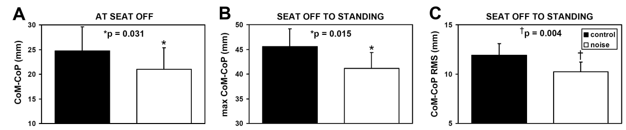


Fig 1: Group mean (SE) CoM-CoP parameters for control and noise conditions

TP-61

Does proprioception contribute to the construction of the subjective vertical?

G. Barbieri[1], A. Gissot[2], F. Fouque[1] and D. Pérennou[2]

[1]INSERM ERM 207, Motricité & Plasticité, Dijon, France and [2]Service de rééducation neurologique - CHU Dijon, Dijon, France

Introduction: Visual, vestibular and somesthetic information are all used to build and update a representation of the vertical. It is well known that visceral graviceptors (Mittelstaedt, 1992) and Golgi tendon receptors (Dietz et al., 1992, Massion et al., 1992) contribute to the postural perception of the vertical whereas the role of the muscular proprioception (muscles spindles, Ia) remains to be clarified. The objective of this study was to analyze whether or not the muscular proprioception contributes to verticality representation. We hypothesized that the manipulation of proprioception by an appropriate tendinomuscular vibration may tilt the normal representation of the vertical in healthy subjects.
Methods: The subjective postural vertical (SPV) was measured in twelve healthy subjects (23.3 ± 1.9 years; 6 females and 6 males) in two conditions: baseline and vibration during the task (both Achilles tendon, frequency 85 Hz, amplitude 0.85 mm). In this latter condition, vibration started 180s prior to the measurements and applied until the task was completed. The presentation of the conditions was baseline first, vibration second for 6 subjects, the reverse for 6 subjects. In each condition the postural perception of the vertical was measured six times. Two indices were obtained for each condition and subject: the SPV orientation (the average of the six measurements) and SPV uncertainty (standard deviation over the 6 measurements).

Results: Achilles tendon vibration induced a systematic backward tilt of the SPV orientation, of 2.7 ± 0.8° magnitude in average (p<10-3) without any significant changes of the SPV uncertainty. **Conclusions:** These findings suggest that proprioception contributes to the representation of the vertical. This could have interesting clinical perspectives for patients presenting a deviation of their subjective vertical. Would vibration applied on appropriate muscles be helpful to recalibrate their sense of verticality, thus improve their balance?

Fear of Falling, Falls and Prevention

TP-62

Stiffening Strategy Maintained at Extreme Surface Heights

J.R. Davis[1], M.G. Carpenter[1] and A.L. Adkin[2]

[1]School of Human Kinetics, UBC, Vancouver, BC, Canada and [2]Department of Physical Education and Kinesiology, Brock University, St. Catherines, ON, Canada

Introduction: Postural anxiety manipulated through changes in surface elevation has been shown to significantly influence the control of upright stance (1). When full vision was available, subjects adopted a stiffening strategy when standing at elevated surface heights up to 1.6m. (1). However, conflicting results have been reported when subjects stood at more extreme heights and when peripheral vision was removed (4,5). Therefore the purpose of this study is to investigate how standing at increased surface heights higher than 1.6m and under reduced peripheral vision affect centre of pressure (COP) displacements during quiet stance. **Methods:** 8 healthy subjects, (4 male; age range 22-30 years) stood quietly on a force plate for one minute durations while elevated from ground level to 0.75m, 1.6m and 3.2m using a hydraulic lift. Three visual conditions were counter balanced at each height: eyes open, eyes closed and while wearing blinders designed to occlude peripheral vision. COP was calculated offline from force plate data (100Hz; 5 Hz low pass filtered) from which RMS amplitude and MPF were derived in anterior-posterior (A-P) and medial-lateral (M-L) directions. At each height under each visual condition subjects' perceived levels of anxiety and confidence were gauged using task specific self-rated questionnaires (1). **Results:** COP measures were significantly influenced by postural anxiety. Independent of visual condition, MPF was significantly influenced by surface height in both the A-P ($F(3,21)=8.5$, $p<0.001$) and M-L ($F(3,21)=8.8$, $p<0.001$) directions. On average, MPF increased by 57% in the A-P and 35% in the M-L directions when subjects were standing at 3.2m compared to ground level. Although not statistically significant, RMS amplitude tended to decrease with increased surface height in the eyes open condition. On average RMS decreased when subjects were standing at 3.2m compared to ground level by 16% and 13% in the A-P and M-L directions respectively.
Conclusions: With increasing heights, subjects adopted a stiffening strategy characterized by higher frequency and lower amplitude COP displacements. These observations contrast reports by Nakahara et al. (2000) and Simeneov and Hsiao (2001) of larger COP displacements at elevations above 3m. Furthermore, altering the amount of peripheral visual input subjects received did not affect COP displacements at higher heights suggesting that the observed changes in COP RMS and MPF were due to psychosocial influences and not height dependent changes in the field of vision. Acknowledgement: NSERC support to MG Carpenter. Refrences: [1]Carpenter et al. 1999. Surface height effects on postural control: A hypothesis for a stiffness strategy for stance. J Ves Res 9: 277-286 [2]Nakahara et al. 2000. Influence of height on the spatial orientation and equilibrium of the body. Head Neck Surg. 123:501-504 [3]Simeonov and Hsiao. 2001. Height, surface firmness, and visual reference effects on balance control. Inj prev 7: (Suppl 1) 50-53

TP-63

Weight loss improves the accuracy of rapid aiming movements

F. Berrigan, M. Simoneau, J. Marcotte, O. Hue, A. Tremblay and N. Teasdale

Université Laval, Ste-Foy, QC, Canada

Introduction: Compare to normal weight persons, obese show a reduced postural stability. In one experiment, a strong association between balance control and body weight was observed with weight explaining up to 62% of the variance observed in balance control; the heaviest persons showing faster center of pressure speed (Hue et al. 2006). This strong association between balance control and body weight was confirmed in a subsequent study showing that weight loss induced by a dietary restriction improves postural stability (Teasdale et al. 2006). Obesity also affects negatively the control of rapid and accurate pointing movements performed from a standing posture (Berrigan et al. 2006). In the present study, we examined whether a weight-loss program induced by a dietary restriction would improve the speed-accuracy characteristics of the aiming.
Methods: Eleven obese subjects (initial BMI ranging from 30.5 to 39.3 kg/m2) participated. All participants were evaluated at baseline (before the weight loss program) and after the weight loss program when they were experiencing resistance to weight loss (resistance). A standard Fitts-like paradigm was used for the aiming responses. Movements were performed from an upright standing and a seated posture. Only target size was modified, movement amplitude was kept constant. Four indexes of difficulty (IDs) were used and were identical for both postures.
Results: On average, participants lost 8.0 kg (± 3.6) and reduced their body mass index (BMI) by 2.6 kg/m2. Waist and hip circumferences decreased by 7.8 cm (± 4.7) and 6.4 cm (± 5.4), respectively. As expected, the duration of the movement increased with an increase task difficulty. After the weight loss program, faster movements were observed (425 ms before the weight loss and 351 ms after). The decrease in movement time was greater when participants aimed in an upright standing posture than when seated (92 ms and 57 ms for the standing and seated posture, respectively). This decrease was observed mainly during the deceleration portion of the movements. (88 ms and 52 ms for the standing and seated posture, respectively).
Conclusions: Before and after weight loss, increasing the task difficulty (by reducing the size of the target) led to longer MT. The key observation, however, is that after the weight loss program, the decrease in movement time was greater when participants were standing than when seated. The greater improvement noted when standing suggests that obesity, because of its effects on the control of balance, imposes additional postural constraints on goal-directed movements.

TP-64

Heel acceleration at heel strike and slip outcome

K. Beschorner and R. Cham

Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: The dynamics of the leading leg, especially heel displacement and velocity, have been the focus of several studies yet few researchers have considered heel acceleration. One study has described heel acceleration during slipping [1], while another study described heel acceleration during swing phase prior to slip initiation [3]. Anterior/posterior heel acceleration may be of interest because it represents the combined effects of leading leg kinetics, which may hold the leading leg reducing the severity of the slip [2]. Heel strike time represents an initial condition to the slip and therefore may be used to identify risk of falling in subjects.
Methods: Sixteen young (aged 20-33) and eleven older (aged 55-67) subjects were consented to participate in the study and donned a safety harness during all trials. A total of 79 markers were placed on the subjects and tracked during the trials to characterize their motion. Subjects walked across a tiled floor surface instrumented with forceplates. Subjects experienced four walking trials: the floor was dry during the first three trials and then a slippery liquid was applied to the floor without their knowledge for the fourth trial. Anterior/posterior heel acceleration of the leading leg was determined at heel strike. Ankle, knee and hip torques of the leading leg were calculated using a bottom up inverse dynamics approach from ground reaction forces measured at the floor. Joint torques were parameterized at heel strike. Slip trials were classified as falls if the hip centers fell 5% below the local minimum of the dry trial.
Results: Recovery subjects were found to have higher posterior heel acceleration at heel strike than fall subjects ($p<0.05$). Posterior heel acceleration at heel strike was found to correlate with ankle dorsiflexion torque ($r=0.61$, $p<0.001$), knee flexion torque ($r=0.84$, $p<0.001$) and hip extension torque ($r=0.68$, $p<0.001$). Therefore subjects who recovered have larger posterior heel accelerations, which seem to be the result of leading leg torques.
Conclusions: The larger posterior heel accelerations at heel strike seem to be a result of leading leg kinetics, particularly the knee torque. Having larger joint torques to pull back the heel at heel strike and early in stance may be beneficial towards slip recovery. Therefore increasing posterior heel acceleration by increasing activity in knee flexors may be beneficial to reducing falls. REFERENCES: 1. Cham, R., Redfern, M.S., 2002. Safety Science 40, 559-576. 2. Cham, R., Redfern, M.S., 2002. Gait & Posture 15, 159-171. 3. Lockhart, T.E., Kim, S., 2006. Gait & Posture 24, 23-34.

TP-65

Effects of age and loss of balance direction on the threshold of balance recovery

A. Telonio[1] and C. Smeesters[1]

[1]Research Center on Aging, Sherbrooke, QC, Canada, [2]Human Performance and Safety Laboratory (PERSEUS), Université de Sherbrooke, Sherbrooke, QC, Canada and [3]Department of Mechanical Engineering, Université de Sherbrooke, Sherbrooke, QC, Canada

Introduction: The effects of age and loss of balance direction on the threshold of balance recovery have not been quantified, despite evidence of their importance during small and medium postural perturbations. Moreover, understanding the effects of age and loss of balance direction are particularly important given that case controlled studies have shown that sideways falls, compared to other fall directions, increase hip fracture risk. Therefore, the purpose of this study is to quantify the effects of age and loss of balance direction on the threshold of balance recovery.
Methods: Balance recovery following sudden release from an initial lean was performed by six healthy younger adults (22.5±4.0yrs) and six healthy older adults (65.2±0.9yrs) with an equal number of males and females in each group. The maximum lean angle that these healthy adults could be released from and still recover balance using a single step was determined for i) forward, ii) dominant side, iii) non-dominant side and iv) backward leans. Lean angles, reaction times, weight transfer times, step times, step lengths and step velocities were measured using force platforms and a motion measurement system. Two-way analyses of variance with repeated measures were used to determine the effects of age and lean direction.
Results: Both age ($p=0.001$) and lean direction ($p<0.001$) significantly affected the maximum lean angles that healthy adults could be released from and still recover balance using a single step. There was also a significant interaction between age and lean direction ($p=0.027$). Moreover, at the maximum lean angles, age and lean direction also affected several of the kinematic variables.
Conclusions: Results have shown that lean direction significantly affects the postural disturbance younger and older adults could sustain. Moreover, the age-related reduction in maximum lean angles is more important for dominant (46%) and non-dominant (41%) leans than for forward (36%) or backward (27%) leans. It is thus conceivable that different mechanisms could be responsible for balance recovery in different directions. Further experiments are needed to confirm these results in a larger sample of younger and older adults.

Effect of lean direction on kinematic variables for younger (YA) and older (OA) adults

Lean Direction	Age	Maximum lean angle (deg)	Reaction time (s)	Weight transfer time (s)	Step time (s)	Step length (m)	Mean step velocity (m/s)	Maximum step velocity (m/s)
Forward	OA	20.1±2.6	0.070±0.007	1.284±0.023	0.216±0.030	0.794±0.043	3.74±0.65	5.17±0.69
	YA	31.3±4.3	0.067±0.013	1.247±0.029	0.190±0.015	0.957±0.089	5.10±0.82	7.32±1.47
Dominant	OA	13.5±6.3	0.085±0.012	1.344±0.076	0.242±0.108	0.529±0.128	2.48±1.06	3.53±1.23
	YA	25.1±3.7	0.080±0.008	1.237±0.037	0.192±0.042	0.702±0.055	3.78±0.77	5.08±0.86
Non-Dominant	OA	14.4±4.6	0.083±0.007	1.292±0.072	0.243±0.092	0.590±0.119	2.59±0.70	3.53±0.70
	YA	24.3±2.3	0.075±0.004	1.262±0.026	0.204±0.032	0.729±0.094	3.63±0.59	4.46±0.51
Backward	OA	14.9±3.6	0.095±0.018	1.235±0.114	0.258±0.031	0.615±0.149	2.44±0.75	3.85±0.93
	YA	20.3±3.1	0.086±0.007	1.179±0.025	0.229±0.034	0.789±0.165	3.44±0.50	5.04±0.97

TP-66

Fear of falling, its psychological components and slip-warning induced gait adaptations in older adults with mild mobility impairments

B. Coley[1], E.J. Lenze[2], S. Perera[3], J. VanSwearingen[4], S. Studenski[3] and R. Cham[1]

[1]Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA, [2]Psychiatry, University of Pittsburgh, Pittsburgh, PA, USA, [3]Geriatric Medicine, University of Pittsburgh, Pittsburgh, PA, USA and [4]Physical Therapy, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: Fear of falling (FOF) is a major public health concern in the elderly [1]. Most gait research in FOF has been con-

ducted in healthy adults. Yet, FOF is most prevalent in populations with mobility impairments [2]. FOF-mediated conservative gait patterns may seem beneficial, however, there is growing evidence revealing mechanisms whereby FOF may aggravate postural control impairments. The goal of this study is to examine the extent to which FOF and its psychological components are associated with the ability to generate appropriate gait adaptations in environments perceived as dangerous, e.g. slippery floors.
Methods: Thirty three subjects (80±6 years old) with mild mobility impairments (Short Physical Performance Battery score between 6-10) were recruited. FOF levels were assessed using the Survey of Activities and Fear of Falling in the Elderly [3]. Other psychological assessments included but were not limited to evaluations of anxiety and depression. All subjects were exposed to two experimental gait testing conditions. In the first condition termed "known dry floor" (baseline), subjects were reassured that the floor would NOT be slippery. In the second condition, "slippery floor warning" state, subjects were informed of the possibility of encountering a slippery floor (in reality the floor was not slippery). Primary gait variables previously linked with slipping or falling risk were the focus of this study and included general spatiotemporal gait characteristics. Primary measures of slip-related gait adaptability (within-subject difference in primary gait variables between warning and baseline condition) were each entered as a dependent variable in multiple regression models. We examined the contribution of (a) each psychological measure alone, (b) FOF alone, and (c) both psychological measures and FOF level simultaneously to the variability in each gait adaptability measure.
Results: The results indicate that, in general, a far greater proportion of the variability in gait adaptability measures appears to be explained by the psychological components of FOF rather than FOF itself. For example, 15-22% of the variability in temporal gait variability changes between warning and baseline conditions are explained by depression scores ($p < 0.05$), compared to less than 1% by FOF alone ($p > 0.1$). Thus, while FOF alone may explain baseline gait characteristics such as stride width ($R2 = 0.27$, $p < 0.01$), psychological components of FOF may be a better indicator of the ability to adapt one's gait in environments perceived as dangerous.
Conclusions: The findings of this preliminary study underline the need to characterize the psychological components of FOF with precision and to include balance/mobility and focused mental health treatments in FOF-related interventions. Funding source: Pittsburgh Older Americans Independence Center References [1] Arfken Am J Public Health, 84:565-70,1994. [2] Bloem J Neurol, 248:950-8,2001. [3] Lachman J Gerontol B Psychol Sci Soc Sci,53:43-50, 1998.

TP-67

Should foot pain be used to discriminate multiple fallers from non-fallers?

K.J. Mickle[1], J.R. Steele[1], B.J. Munro[1], S.R. Lord[2] and H.B. Menz[3]

[1]Biomechanics Research Laboratory, University of Wollongong, Wollongong, NSW, Australia, [2]Prince of Wales Medical Research Institute, Sydney, NSW, Australia and [3]Musculoskeletal Research Centre, LaTrobe University, Melbourne, VIC, Australia

Introduction: Falls in the elderly are a major health concern, but the causes are multifactorial[1]. Although foot pain has been found to impair balance, gait and functional ability in older men and women[2], it is unknown whether foot pain is an independent risk factor for falling. With approximately one-third of older people suffering from foot pain[3], it is important to determine whether foot pain is a falls risk factor. Therefore, the aim of this study was to determine whether foot pain was able to discriminate between older individuals who were non-fallers compared to those who had experienced multiple falls.
Methods: Three hundred older men and women aged between 60-90 years were randomly recruited, using the electoral roll, from the Sydney and Illawarra regions of NSW, Australia, to participate in the study. Each subject completed the Manchester Foot Pain and Disability Index (MSPDI)[4] and the short form Physiological Profile Assessment (PPA)[5]. All participants were then followed prospectively to determine falls incidence over the following 12 months. Individuals who recorded a fall were categorised as either singular fallers (1 fall only) or multiple fallers (≥ 2 falls) and were then compared to age- and gender-matched non-fallers to determine whether foot pain differed between fallers and non-fallers. As the foot pain scores were not normally distributed a Kruskal-Wallis test was used to determine between-group differences; if significant, pairwise comparisons were conducted using the Mann-Whitney U test ($p \leq 0.05$).
Results: When the singular and multiple fallers were combined as a group and compared to the non-fallers, no significant differences were found in the foot pain scores obtained using the MSPDI. However, significant between-group differences were found when the multiple fallers only were compared to the non-fallers ($\chi 2 = 10.41$; $p = 0.005$). That is, the multiple faller's foot pain score (13.17 ± 9.76) was significantly higher than both the individuals who had only sustained one fall (4.72 ± 6.68; $p = 0.006$) and the non-fallers (3.93 ± 6.43; $p = 0.002$), whereby a higher MSPI score indicates greater disabling foot pain. Interestingly, there were no between-group differences in the PPA falls risk score ($\chi 2 = 0.28$; $p = 0.869$).
Conclusions: When compared to singular and non-fallers, older men and women who have had multiple falls, suffer more disabling foot pain as scored using the MSPDI. Furthermore, the foot pain score was better at distinguishing multiple fallers than the more commonly used falls risk score obtained using the PPA. Therefore, the MSPDI may be a valuable screening tool to identify older men and women at risk of falling. References: 1. Tinetti et al, N Engl J Med 319: 1701-7, 1988 2. Leveill et al, Am J Epiedemiol 148:657-65, 1998 3. Menz et al, Rheumatology 45:863-867, 2006 4. Garrow et al, Pain 110:378-84, 2004 5. Lord et al, Phys Ther 83:237-252, 2003

TP-68

Experience related differences in performance of martial arts sideways fall techniques

B. Groen[1], V. Weerdesteyn[2] and J. Duysens[2]

[1]Research Development and Education, Sint Maartenskliniek, Nijmegen, Netherlands and [2]Department of Rehabilitation Medicine, Radboud University Medical Centre, Nijmegen, Netherlands

Introduction: Hip fractures are a major health problem for the elderly. About 90% of hip fractures are caused by falls. Sideways falls with direct hip impact have most risk for hip fractures. It has been shown that martial arts techniques (MA) reduce hip impact force in sideways falls in experienced fallers (Groen et al., 2006, Sabick et al., 1999), as well as in young adults with no prior experience after a short MA fall training (Weerdesteyn et al., 2006). The amount of reduction was larger in the experienced group, indicating the presence of experience-related differences in the performance of MA techniques. The purpose of the present study was to identify experience-related differences in movement pattern of MA fall techniques.

Methods: Nine young females (non-judo), who received a 30-minutes fall training and 6 female experienced martial artists (judo) performed sideways falls from kneeling position onto a force plate covered with judo mats. Falls started after voluntarily release of a grip that supported the subjects at 21 degrees lean angle from the vertical. Each subject performed 12 MA falls. In MA falls, the fall is changed into a rolling movement. Subsequently, the arm is used to break the roll. In addition, the non-judo group performed 12 falls imitating the technique most elder people use spontaneously. The latter is called the block technique because the outstretched arm is used to block the fall. Kinematic data were collected with a 3D-video system (Primas) and forces were measured with a Bertec force plate (size: 1.2 by 1.2 m).

Results: In agreement with previous data (Weerdesteyn et al., 2006), hip impact force was 12% lower in MA than in Block falls ($p=0.004$) in the non-judo group. In the MA falls, hip and shoulder impact forces were not significantly different between the judo and non-judo group. Arm impact was larger for the judo group ($p=0.014$), reflecting a more powerful use of the arm to break the fall. In the judo group, impact occurred first at the hip impact, then at the arm impact and finally at the shoulder as found for people experienced in aikido (Sabick et al., 1999). However, shoulder impact occurred prior to arm impact in 4 of 9 subjects of the non-judo group. After release the judo group moved the trunk gradually downward to a more horizontal orientation. In contrast, the non-judo group started with an upward trunk movement prior to the downward movement of the trunk. At hip impact, trunk orientation in MA falls was more horizontally in the judo than in the non-judo group ($p<0.001$). After hip impact, the vertical trunk velocity was generally bi-modal in shape, with the second peak less pronounced in the judo group, indicating a smoother hip landing.

Conclusions: In conclusion, to further improve MA fall techniques training should focus on the timing of hand impact, a reduction of an upwards trunk movement, a horizontal trunk orientation at hip impact and a smoother hip landing.

TP-69

The impact of anticipating slippery floors on spatial and temporal variability during gait

A. Chambers and R. Cham

Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: Falls are a major cause of injury, death, and disability in the elderly. Proactive strategies generated to maintain balance in the face of an anticipated external disturbance have been investigated using testing paradigms involving repeated exposure to a known perturbation [1,2]. The goal of this study, which has not been previously addressed, is to investigate the impact of anticipating real slippery floors on the spatial and temporal variability during gait on dry surfaces. Gait variability has been linked with falls [4].

Methods: Eighteen young (20-33 yrs) and thirteen older subjects (55-67 yrs), screened for neurological and orthopedic abnormalities, were instructed to walk at a self-selected pace across a vinyl tile walkway, while whole body motion data were sampled at 120 Hz. Subjects were informed the first few trials would be dry, 'baseline dry' (BD). Without the subjects' knowledge, a glycerol solution was applied at the left/leading foot-floor interface, generating an 'unexpected slip. Subjects were then alerted that all remaining trials might be slippery, 'alert dry' (AD). General spatiotemporal gait characteristics and spatial/temporal gait variability were derived and compared between BD and AD conditions using mixed-linear regression models. Statistical significance was set at 0.05.

Results: In general, anticipation resulted in shorter mean durations of the temporal aspects of gait. Older adults tended to have increased temporal variability (root mean square (rms) values of single support and stance duration) when compared to young adults. Both cadence and gait speed increased in AD trials with young adults showing the greatest increase in gait speed during anticipation. Additionally, changes in spatial variability were noted during AD with decreased rms and increased rms of step width and step length, respectively.

Conclusions: In summary, anticipating slippery floors is associated with a few gait adaptations that are beneficial, e.g. increased cadence reduces the risk of experiencing a hazardous slip [3]. Only older adults demonstrated a tendency toward increased temporal variability when anticipating a slippery surface; both age groups increased step length variability, suggesting the generation of proactive strategies is perhaps not as "automatic" as normal gait. Finally, anticipation resulted in decreased step width variability potentially due to the increased cadence results previously mentioned. Previous research has reported that step width variability is an important factor in fall risk and fall history [4]. References 1. Cham R et al. Gait and Posture, 15:159-71, 2002. 2. Marigold DS et al. J Neurophysiol, 88(1):339-53, 2002. 3. Moyer BE et al. Ergonomics, 49(4):329-343, 2006. 4. Brach JS et al. J NeuroEng & Rehab, 2(21): 2005.

TP-70

Do judo athletes utilize ukemi falling techniques during unexpected sideways falls?

F. Feldman and S.N. Robinovitch

School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada

Introduction: Certain sports activities provide participants with training in safe falling strategies that might be utilized to advantage during unexpected real-life falls. A notable example is training of "ukemi" in judo, which involves impacting the ground with a rolling motion, to distribute impact energy and contact force (Groen et al., 2006; Sabick et al., 1999). However, it is not known whether judo athletes utilize ukemi during unexpected falls. To test this, we compared the falling patterns of judo athletes and control participants who attempted to maintain their balance when subjected to a strong postural perturbation. We

hypothesized that, in the event of a fall, judo athletes would exhibit quantitatively different landing strategies than untrained participants.
Methods: Study participants consisted of 15 male judo athletes with at least 5 years of experience (mean age=34 years (SD 9)) and 13 healthy male controls (mean age=21 years (SD 2)). During the experiment, the participant stood on top of a large platform (covered with gym mats) that was made to translate horizontally by means of a linear motor. The primary focus of analysis was the first trial, where we instructed participants that "your balance will be perturbed, and your goal is to maintain your balance." In order to minimize pre-planning of the postural response, no information was provided about the compliance of the ground, or the direction or speed of the perturbation. Judo athletes underwent a second trial involving the same perturbation characteristics, where we instructed them to fall using the ukemi technique. In each trial, we measured the 3D positions of 21 skin surface markers at 240 Hz.
Results: In the first trial, 60% of judo athletes and 85% of control participants fell and impacted their trunk or pelvis. Both groups exhibited similar falling strategies, characterized by failed attempts to recover balance by stepping, followed by ground impact to the knee and outstretched hands, and finally impact to the hip. Furthermore, there were no differences between groups in mean values of hip impact velocity (judo=2.89 m/s (SD 0.81); control=2.68 m/s (SD 1.04); p=0.630) and trunk angle at hip impact (judo=37 deg (SD 14); control=49 deg (SD 13); p=0.056). All judo athletes were able to successfully execute the ukemi falling strategy in the second trial.
Conclusions: Our results suggest that judo training has little effect on the sideways falling strategy that emerges following a failed attempt to recover balance. When participants focused on "maintaining balance" (a common goal in real-life falls), a similar falling strategy emerged in judo athletes and control participants. However, our results also suggest that falling patterns can be influenced by central set (i.e., priority on balance recovery versus safe landing). This supports the notion that, with sufficient time and attention, individuals can voluntarily select from a repertoire a falling strategy that is safest for a given perturbation and environment.

TP-71

Influences of center of pressure and body segment movements on perceptions of postural stability

A. DiDomenico, K. Gielo-Perczak, R.W. McGorry and C. Chang

Liberty Mutual Research Institute for Safety, Hopkinton, MA, USA

Introduction: Research supports the capability of individuals to perceive differences in postural sway, measured using the changes in center of pressure (COP), due to changes in task or environmental conditions [1, 2]. However, the influence of specific body segment movements has not been investigated. The aim of this study was to investigate the influence of the movement of the COP and individual body segments on perception of postural stability.
Methods: Twenty-five healthy men aged 18 to 55 participated. The experimental protocol consisted of quiet standing in a tandem stance with varying experimental and task conditions, including standing on a slightly elevated beam with a single-handed load. A motion tracking system was used to collect position displacement data, sampled at 100 Hz, from sixteen 10 mm diameter reflective markers located on the trunk, upper and lower limbs. Common measures of postural sway were calculated for the displacement of the COP in both the antero-posterior and medio-lateral directions (e.g. range, elliptical area, mean velocity). A procedure developed by Schieppati et al. [2], including a simple subjective scale of stability (0-unstable and 10-stable), was used to evaluate and quantify perceptions of stability throughout a trial.
Results: Correlation and regression analyses indicated a stronger association of subjective stability ratings with movements of body segments as compared to displacement or velocity of the COP. The placement of the arms relative to the sacrum and small position modifications of the forward limb (left leg) had the greatest impact on perceptions of stability, with up to a three times greater correlation values as compared to COP. Multiple linear regression models using the location and displacement of body segments to predict subjective ratings of postural stability explained five times more of the variability within the data.
Conclusions: The subjective evaluation of postural stability may provide an adjunct and easily implemented method to assess balance. An important aspect of evaluating stability was the kinesthetic feedback individuals received from the lower limbs. Load carriage results suggest that the location of the arms, and thus the load, also significantly influenced perceptions of stability. Although displacement of the COP is generally used to assess postural stability and balance during quiet standing, it would seem that individuals are focusing key movements of individual body segments that may be task dependent, whereas the COP is a sum total of pressure created by the entire body. **References:**
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TP-72

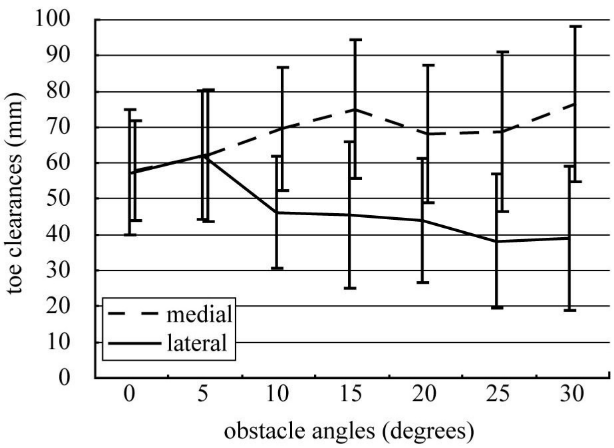
Gait analysis of participants stepping over tilted obstacles

Y. Kobayashi[1], Y. Mine[1] and H. Fujimoto[2]

[1]*Graduate School of Human Sciences, Waseda University, Tokorozawa City, Saitama, Japan and* [2]*Faculty of Human Sciences, Waseda University, Tokorozawa, Saitama, Japan*

Introduction: Failure to avoid unexpected obstacles encountered while walking may result in stumbling. Many studies have therefore been carried out regarding the movements related to obstacle avoidance. However, most of these studies have regarded movements made while stepping over level obstacles. We also need to know the effects of nonlevel obstacles on obstacle-avoidance movements since some of the obstacles encountered in daily lives are not level. The purpose of the present study was to determine the effects of nonlevel obstacles on obstacle-avoidance movements.
Methods: Twenty healthy young adults were randomly separated into two groups and were asked to step over obstacles at various

heights and angles (0 degrees / 25 mm, 50 mm, 75 mm), and six frontally tilted obstacles (5 degrees, 10 degrees, 15 degrees, 20 degrees, 25 degrees, and 30 degrees). One group stepped over lateral-low and medial-high tilted obstacles, while the other group stepped over lateral-high and medial-low tilted obstacles. From the collected data, we defined toe clearances calculated from a marker placed on the 1st metatarsal as medial toe clearances and toe clearances calculated from the marker placed on 5th metatarsal as lateral toe clearances, and compared them between the level and tilted obstacles.
Results: No significant differences in lateral and medial toe clearances were seen among the level obstacles of varying heights. However, when the subjects stepped over the lateral-high and medial-low tilted obstacles lateral toe clearances significantly decreased in comparison with the level obstacles.
Conclusions: These results suggest that when people step over lateral-high and medial-low tilted obstacles, they cannot raise their feet as easily as they do when they step over level obstacles, causing an increase in the chance of stumbling.



Toe clearances while stepping over lateral = high / medial = low tilted obstacles (lateral-solid, medial-dotted).

TP-73

The Dynamic Gait Index provides insight into stair climbing and fear of falling in healthy elderly men and women

T. Herman[1], G. Yogev[1], M. Brozgol[1], N. Inbar-Borovsky[1], N. Giladi[2] and J.M. Hausdorff[4]

[1]Laboratory for Gait & Neurodynamics, Tel-Aviv Sourasky Medical Center, Tel Aviv, Israel, [2]Movement Disorders Unit, Tel Aviv Sourasky Medical Center, Tel- Aviv, Israel, [3]Sackler School of Medicine, Tel Aviv University, Tel- Aviv, Israel and [4]Division on Aging, Harvard Medical School, Boston, MA, USA

Introduction: The Dynamic Gait Index (DGI) has been developed as a clinical tool to assess gait, balance and fall risk. Previous studies using the DGI have focused on subjects with vestibular and gait disorders. Because the DGI evaluates not only usual steady-state walking, but also walking during more challenging tasks such as while rotating one's head, while accelerating, and when climbing stairs, it may be an especially sensitive test. The purpose of this study was to better understand the DGI, and its relationship to other tests and fear of falling (FOF), in a relatively healthy, highly functional group of older adults.
Methods: This report is based on data on 213 older adults (mean:76.5+/-4.7 yrs; 60% women) who could walk independently and who were free from neurodegenerative disease, dementia, and other pathologies likely to directly affect gait or cognitive function. Measures included the Dynamic Gait Index (DGI), the Berg Balance Test (BBT), the Timed Up and Go (TUAG), the Mini-Mental State Exam (MMSE), the Unified Parkinson's Disease Rating Scale (UPDRS) motor portion (a test quantifying bradykinesia and extrapyramidal symptoms), the Activities-Specific Balance Confidence (ABC) scale and the # of falls in the past year.
Results: The DGI was moderately correlated with BBT (r=0.53; p<0.001), the TUAG (r=-0.42; p<0.001) and the ABC (r=0.49; p<0.001). Scores on the DGI were near perfect in men (23.3+/-1.2), but among women, there was a small, but significant (p<0.001) decrease in the DGI (22.7+/-1.6). Whereas pivoting, head turning, and other DGI items were not different in men and women, this reduction in the total DGI score in women was due primarily to stair climbing performance (p<0.001), with many women choosing to walk while holding a handrail. Scores on the BBT (men: 54.1+/-2.4; women: 54.0+/-2.4; p=0.74) and the TUAG (men: 9.5+/-1.8 sec; women: 9.8+/-1.7 sec; p=0.28) were similar in men and women and indicative of good functional mobility and balance. UPDRS and MMSE scores were also similar in the two groups (p>0.22). On the other hand, ABC scores (men: 94.5+/-8.3; women: 89.9+/-11.4; p=0.025) and fall history (men: 16.2%; women: 30.2%; p=0.039) were different. Still, the gender-difference in DGI scores persisted if we adjusted for ABC scores or when subjects were stratified by fall history.
Conclusions: Given its ability to identify subtle changes in performance, the DGI appears to be an especially appropriate tool for assessing function in healthy older adults. Application of the DGI indicates that among relatively healthy older adults, men and women's approach to stair climbing is different. While fear of falling and fall history contribute to this gender-specific attitude towards stair climbing, other as yet unidentified factors apparently also play a role. This should be considered when applying the DGI and when evaluating functional independence and fall risk in older adults.

TP-74

Factors associated with balance problems in older individuals with diabetes

H. Corriveau[1], H. Sveistrup[2], M. Marchand[1], F. Cabana[1] and A. Cisse[1]

[1]Réadaptation, Université de Sherbrooke, Sherbrooke, QC, Canada and [2]Occupation Therapy, University of Ottawa, Ottawa, ON, Canada

Introduction: Older people with diabetes are at greater risk of falling than those without diabetes. Poor balance has been identified as an important causal factor of falling among diabetic older persons with or without peripheral neuropathy (PN). PN includes a predominant sensory dysfunction and motor dysfunction to a lesser degree, usually distally in the lower limbs. Studies have shown that such lower-limb deficits contribute to

postural instability or balance problems. Because diabetic PN is irreversible, improvement in balance relies on targeting factors that can be altered. In this context, the purpose of this study was to identify specific modifiable risk factors for balance problems among the subgroup of older people with diabetes.
Methods: Balance was evaluated with the single-leg stance test. Single-leg stance testing is recognized to be a quick and objective measure for identifying the elderly living in the community with slight balance problems related to mild PN. Four factors (somatosensory, vision, strength of the muscles of the lower extremity, attention demand) related to physiological subsystems and an evaluation of fear of falling were considered as possible predictors of balance control. The somatosensory evaluation included evaluation of touch-pressure and vibratory perception thresholds. Vision was evaluated by distal acuity. The strength of the main muscles of the lower extremity was measured. The capacity for sustained attention was measured with a letter cancellation test. Fear of falling was measured as the degree of self-confidence in avoiding a fall during the performance of different tasks. The degree of PN was quantified using a valid clinical scoring system developed by Valk. Univariate associations between risk factors and outcome (single-leg stance) were analyzed. Variables showing statistically significant associations ($p<0.05$) in the bivariate analysis were entered into a backward stepwise multivariate regression analysis.
Results: A total of 44 men and 42 women (73.74 years ±5.82) who had been diagnosed with diabetes for a mean of 11.61 years (±9.40) were evaluated. Sixty-two percent had PN. Nine independent variables were retained with the bivariate analysis: fear of falling, PN severity, attention demand, age, TUG, quadriceps muscle strength, and touch-pressure and vibratory perception thresholds. Multivariate regression controlling for age demonstrated that PN, fear of falling and attention demand were associated with increased balance problem ($F = 12.64$; $p = 0.001$). The model is stable and explains 33% of the variation in balance recorded using single-leg stance.
Conclusions: In addition to the severity of neuropathy, two risk factors were identified (cognitive problem and fear of falling) that contribute to increased falls in this population. These results suggest that interventions focusing on cognitive demand and fear of falling should be implemented as part of the rehabilitation balance programs for diabetic patients with PN.

TP-75

Postural balance and self-reported balance confidence among older adults with hip fracture history

S.E. Sihvonen[1], M. Kallinen[3], I. Kiviranta[3], M. Alén[2] and S. Sipilä[2]

[1]Injury Prevention Unit, National Public Health Institute, Helsinki, Finland, [2]Department of Health Sciences, University of Jyväskylä, Jyväskylä, Finland and [3]Central Hospital, Central Finland, Jyväskylä, Finland

Introduction: Older adults with hip fracture history are shown to be in a high risk for further falls. Balance problems and fear of falling are among key factors behind a high fall risk. The aim of this study was to examine differences in balance control and in balance confidence between groups of older hip fracture patients (HFG) and their non-fractured counterparts (NFG).
Methods: This study is a part of a larger study on hip fracture patients' health and functional capacity. Participants were identified from inpatient records at the Central Finland Central Hospital. All 60-85 year-old patients who had been operated on hip fracture within ½-7 years were potential participants (N=452). 75 hip fracture patients and 31 persons without a hip fracture history participated in baseline measures. Functional balance was measured using Berg Balance Scale (BBS). Dynamic Stability (DS) was tested by computerized force platform test, in which the subject was asked to move his centre of pressure along a track shown on a computer screen and the performance time was measured. Balance confidence was assessed with Activity-specific Balance Confidence (ABC) scale. For 16 specific activities of daily living, the participants were asked how confident they were in not losing their balance or becoming unsteady. Answers were rated from 0 (no confidence) to 10 (complete confidence).
Results: A significant difference (BBS $p<0.001$, DS $P=0.030$) between groups of HFG (BBS mean=46±9, DS mean=11,3±7,1) and NFG (BBS mean=53±3, DS mean = 8,8±3,5) in balance tests was found, indicating that functional balance problems and slower performance in lateral weight-shifting were more common among the HFG compared to the NFG. Similarly, in the ABC-scale the HFG (mean % =59,4) had lower score, showing loss of balance confidence, compared to the NFG (mean %=78,1) and a significant difference ($p<0.001$) between groups was found.
Conclusions: Findings of this study showed that previous fracture complicates balance control in older hip fracture patients and they reported loss of balance confidence during daily tasks. Significant differences found between groups in balance control and balance confidence warrant the use of BBS, DS and ABC tests as tools to asses balance control and balance confidence when programs to rehabilitate and prevent further falls among hip fracture patients are planned.

TP-76

Effects of Tai Chi exercise on clinical measures of balance and attention demand in older individuals with moderate diabetic peripheral neuropathy

H. Corriveau[1], H. Sveistrup[2] and M. Tousignant[1]

[1]rehabilitation, Université de Sherbrooke, Sherbrooke, QC, Canada and [2]Occupation Therapy, University of Ottawa, Ottawa, ON, Canada

Introduction: Approximately 50 % of people with diabetes mellitus over age 60 show evidence of peripheral neuropathy (PN). Older persons with diabetic PN are at increased risk for falls with poor balance identified as an important cause. Furthermore, diabetes has been associated with cognitive dysfunction such as an increased attention demand which is related to balance problems. The movements of Tai Chi have been proposed to improve balance. Tai Chi consists of voluntary body movements which direct the performer's attention to the sensory information, facilitating sensorimotor integration in the movement preparation and execution. Since the decrease in efficiency of balance control recorded in older adults with PN can be attributed, at least in part, to a decrease in sensory information, it can be hypothesised that Tai Chi exercises could improve balance in these people. The purpose of the study was to determine the efficacy of a

12-week Tai Chi intervention on clinical measures of balance and attention demand in diabetic elderly with mild PN.

Methods: Community-dwelling older individuals with diabetic PN were randomly assigned to a standardised (n=20) and a Tai Chi (n=21) exercise group. In order to obtain comparable groups, the sample was stratified by blocks of 4 based on the severity of PN. Tai Chi classes were taught by a Tai Chi instructor who followed the classical Yang style with 28 forms that could be completed during the 12-weeks. The control group received a standard exercise intervention consisting of aerobic training and flexibility. Both programs consisted of two 45-minute exercise sessions per week for duration of 12 weeks. Dependent variables included functional balance (Berg Balanced Scale, single leg stance), walking performance (Timed up and Go (TUG) and walking tandem) and attention demand (TUG manual ((carry a glass of water while walking)) and Double cancellation test).

Results: At baseline, the two groups were comparable with regard to demographic descriptors with no statistical differences in severity of PN (group means of 11/33) or for key values for balance, walking performance and attention demand. The compliance was 93% for the Tai Chi group and 88% for the standardised exercise group. Tai Chi participants showed significant improvements in Berg balance scale ($p < 0.04$), walking tandem and TUG manual ($p < 0.05$). The control group improved significantly on the Double cancellation test ($p < 0.02$).

Conclusions: The study findings support the proposition that Tai Chi improves functional balance and attention demand in elderly with mild diabetic PN. The standardized exercise program also resulted in improvements on a measure of attention demand. Taken together, these results suggest that although community-dwelling older individuals with diabetic PN are at greater risk of functional balance impairment including falls, these individuals could benefit from a Tai Chi program. This intervention could reduce the need for health care related to falls and their consequences.

TP-77

Effect of increasing task complexity on balance (confidence) in experienced leg prosthetic users

C.J. Hofstad[1], R. Beukenkamp[1], H. van der Linde[1] and A.C. Geurts[2]

[1]St Maartenskliniek Research Development & Education, Nijmegen, Netherlands and [2]Dept. of Rehabilitation, Radboud University Medical Centere, Nijmegen, Netherlands

Introduction: Persons using a leg prosthesis often have balance problems and a serious fear of falling. A common consequence of such fear is that subjects avoid activities, which reduces their balance skills. In this study, static and dynamic balance were compared between trans-tibial (TT) and trans-femoral (TF) amputees, and healthy persons. In addition, it was investigated whether postural instability is associated with increased anxiety levels.

Methods: Eight TT amputees, 11 TF amputees and 12 controls stood quietly on a dual-plate force platform during 3 conditions: with eyes open (EO), while performing a dual task (DT), and with eyes closed (EC). All were very experienced prosthetic users. All tasks lasted 30 sec and were performed either on a stable or on a compliant surface (foam). In addition, participants performed a voluntary weight-shifting task on a stable surface, guided by visual feedback of their center of pressure (COP). After each task, participants scored their level of experienced anxiety on a 10-point VAS scale.

Results: The amputees showed 7-8% weight-bearing asymmetry (WBA) in favour of the nonprosthetic foot. WBA increased significantly with increasing task complexity (EC > DT > EO) (foam > stable). All participants showed an increase in lateral and antero-posterior RMS COP velocity with increasing task complexity (EC > DT > EO) (foam > stable) with an interaction effect between condition and surface for all groups. Overall, there were no significant differences in WBA or postural instability between the TT and TF group. Asymmetry of kinetic regulation activity (higher RMS COP velocity under the nonprosthetic versus the prosthetic foot) was equally observed in TT and TF patients. This kinetic asymmetry increased while standing on foam, particularly in the lateral direction. Compared to static balance, both amputation groups showed only a moderate decrease in the ability to make voluntary weight shifts. Balance confidence in all amputees decreased gradually with increasing task complexity (EC < DT < EO) (foam < stable), whereas the controls showed loss of confidence only when standing with EC on foam. Across all participants, loss of balance confidence was associated with decreased postural stability.

Conclusions: Even very experienced TT and TF amputees show substantial loading asymmetry, postural instability and kinetic regulation asymmetry during sensory, cognitive and mechanical task manipulations. In contrast, voluntary control of weight shifting is only moderately affected. Anxiety levels are associated with greater postural instability. Apparently, balance confidence is related to the regulation of basic equilibrium reactions, which seem equally affected in TT and TF amputees. This finding suggests that loss of lower leg muscle control and proprioception affect balance (confidence) more than loss of thigh and knee muscle control and proprioception. Balance (confidence) is an important therapeutic goal in amputee rehabilitation, especially in complex conditions.

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Somatosensory Functions

WP-1

Vibratory thresholds test as a novel examination for patients with somatosensory disorders

M. Ushio[1], M. Toshihisa[2], Y. Chihara[1], S. Iwasaki[1], T. Yamaguchi[3] and K. Kaga[1]

[1]Otolaryngology, Graduate School of Medicine, University of Tokyo, Tokyo, Japan, [2]Otolaryngology, Tokyo Postal Services Agency Hospital, Tokyo, Japan and [3]Biostatistics / Epidemiology and Preventive Health Science, School of Health Science and Nursing, University of Tokyo, Tokyo, Japan

Introduction: Dizziness and unsteadiness during standing and walking are sometimes caused by somatosensory system disorders including vibratory sensation. However, the association of vibratory thresholds (VTs) with balance in patients with somatosensory disorders has been rarely reported. The aim of this study was to evaluate the difference of vibratory sensation between patients with somatosensory disorders and healthy volunteers and to provide a means for evaluating somatosensory disorders in patients with balance problem.
Methods: Using a vibrometer and a posturography, VTs and oscillation during standing in 108 healthy volunteers without past medical histories (age: 17-79) and 19 patients with disequilibrium supposed to be due to somatosensory disorders (age: 60-79) were evaluated.
Results: In healthy volunteers, plantar-VTs showed high positive correlation with age. Total length of path, envelope area (ENV), and VTs of plantar-surface were significantly larger in patients with disequilibrium due to somatosensory disorders than in healthy volunteers. Results of regression analyses showed VTs ≥ 28dB of plantar-surface at 125 Hz and ENV ≥ 10cm2 were critical indexes to diagnose patients as having somatosensory disorders.
Conclusions: VTs test of plantar-surface seemed to be useful as a clinical examination for patients with disequilibrium due to somatosensory disorders, as well as posturography.

WP-2

The Effects of Podokinetic Conditioning on Static and Dynamic Posture

M.A. Hollands, W.R. Young and G.J. Chapman

School of Sport and Exercise Sciences, University of Birmingham, Birmingham, UK

Introduction: Following periods of walking on a rotating disc, individuals inadvertently and unconsciously turn in circles when subsequently asked to close there eyes and step in place on the floor. It has been hypothesized that this phenomenon, termed podokinetic after-rotation (PKAR), results from the relative rotation of the head and trunk with respect to the feet during each stance phase of PKAR in a manner similar to that experienced during walking on the rotating disc (PKAR acquisition). However, to date, there is no published data describing the relative rotations of the head, trunk and feet during PKAR acquisition and expression. Similarly, it is not known whether disc walking results in altered static body posture or if it is a purely dynamic, gait-specific adaptation. Without this information it is not possible to fully understand the mechanism underlying the after-effect. The aim of the current study was to provide this missing information.
Methods: Young adults (n=4) stepped in place for 15 mins on a rotating disc (clockwise 60°/s). Participants were then blindfolded and asked to step in place on the floor for 30 mins. For each walking task, participants stepped in time with a metronome at either a medium (120 steps/min) or a fast (168 steps/min) cadence. Each participant took part in four sessions on separate days. Each session involved one of four combinations of stepping cadence (medium-medium, medium-fast, fast-medium and fast-fast). Prior to the start of floor walking, and then every three minutes, participants stood still for 10s so that there standing posture could be recorded. A 13 camera Vicon MX motion analysis system was used to record full body kinematics for 10s periods at regular intervals during PKAR acquisition and expression.
Results: We found a statistically significant effect of disc walking on both static standing and dynamic posture during the stance phase of walking characterized by head and trunk rotation over the feet in the same direction as PKAR. The size of the postural realignment decayed over time in a similar manner to that observed for PKAR velocity. The cadence of walking, either during PKAR acquisition or expression, had no effect on the size of the relative rotation between head, trunk and feet during static standing or during the stance phase of floor walking. However, increasing the cadence of floor walking resulted in greater PKAR velocity.
Conclusions: Our results support previous findings suggesting that it is the velocity of foot rotation during disc walking that determines the size of PKAR and quantitatively demonstrate that PKAR results from head and trunk rotation over the feet during the stance phase of walking. Our findings also suggest that general postural reorganization of the "neutral" angular relationship between the upper body and feet is, at least partially, responsible for PKAR. We propose that PKAR may be a manifestation of a peripheral adaptation of the lower limb somatosensory system rather than a central process.

WP-3

Internal representation of head, shoulder and body orientation: The role of hand dominancy

I. Paulus, S. Brumagne, S. Knapen and I. Vileyn

Rehabilitation Sciences, KU Leuven, Heverlee, Belgium

Introduction: Proprioceptive signals from the neck muscles have been shown to play an important role in the control of posture. The purpose of this study was to examine whether hand dominancy plays a role in the way proprioceptive signals from the neck muscles are processed.

Methods: Muscle vibration, known as a strong way to activate muscle spindles, was used in this experiment to manipulate proprioceptive signals from the neck muscles. Postural sway characteristics and head and shoulder movements of 12 right-handed and 5 left-handed persons were evaluated in upright posture during different conditions: 1. quiet stance, 2. vibration of the right upper trapezius muscle, 3. vibration of the left upper trapezius muscle. To determine whether the subjects where right- or left-handed the Oldfield Questionnaire was used. During all conditions glasses were used to occlude vision.
Results: A significant difference exists between head movements during vibration of the left trapezius muscle compared to vibration of the right trapezius muscle in the right-handed group ($p<0.05$). During vibration of the right side, there is a significant head bending to the right ($p<0.05$). However during vibration of the left side, there is no significant head movement. A significant difference in head movements was found between left- and right-handed persons for left side vibration ($p<0.05$), but not for right side vibration. Left-handed persons move their head to the right during right side vibration and to the left during left side vibration. Right-handed persons showed small, but significant ($p<0.05$), elevations of both shoulders during vibration of the right side but not during vibration of the left side, in spite of the increase in muscle activity on both sides during both conditions ($p<0.05$). Centre of pressure (CoP) moves significantly forward in both groups and during both conditions ($p<0.05$). No differences were found for CoP movements between both groups and between left or right side vibration.
Conclusions: The results suggest that in right-handed persons both sides play a role in the control of whole body posture, while the proprioceptive signals from the left side are less important for the local control of head and shoulder position. This is not the case in left-handed persons, which is not surprising as the world is organized for right-handed persons. In right-handed persons there seems to be an increase in the gain of proprioceptive signals originating from neck muscles of the dominant side. The egocentric reference frame for the interpretation of proprioceptive signals from the neck muscles seems to be dominant side-centered.

WP-4

A FLEXIBLE POSTURAL CONTROL STRATEGY IN YOUNG AND MIDDLE-AGED PERSONS COMPARED TO YOUNG PERSONS WITH LOW BACK PAIN

S. Brumagne[1], I. Paulus[1], E. Johanson[2] and S. Knapen[1]

[1]Rehabilitation Sciences, University of Leuven, Leuven, Brabant, Belgium and [2]Institute of Exercise Biology and Physiotherapy, University of Tartu, Tartu, Estonia

Introduction: Persons with recurrent low back pain (LBP) have been observed to have altered proprioceptive postural control (Brumagne et al., 2004). These patients adopt a body stiffening strategy and rely more on ankle proprioception to control their posture during quiet upright standing. The purpose of this study was to investigate whether persons with recurrent low back pain use the same proprioceptive postural control strategy despite changing postural conditions compared to healthy young and middle-aged persons.

Methods: Twenty young persons with recurrent LBP and 28 (20 young and 8 middle-aged persons) healthy individuals participated in this study. All subjects had an average physical activity level. The ages of the young persons ranged from 20 to 26 years, the ages of the healthy middle-aged persons ranged from 38 to 53 years. Postural sway characteristics were evaluated in upright posture with or without standing on foam for the conditions as follows: 1) control (no vibration); 2) vibration of the triceps surae muscles; 3) paraspinal muscle vibration; 4) vibration of the tibialis anterior muscles. Vision was occluded in all conditions. All trials lasted 60 seconds. Vibration (60 Hz, 0.5 mm), as a potent stimulus for muscle spindles, was initiated 15 seconds after the start of the trial for a duration of 15 seconds. Descriptive statistics were calculated. An analysis of variance on one factor was used to assess the differences in proprioceptive control ratios between the healthy persons and the persons with LBP.
Results: Persons with recurrent LBP showed significantly different postural control strategies favoring ankle muscle proprioceptive control (ratio closer to 1) instead of paraspinal muscle proprioceptive control (ratio closer to 0) for both postural conditions, i.e., standing on a stable support surface (ratio ankle muscle/ paraspinal muscle control= 0.80) ($F(1,46)= 8.17$, $p<0.05$) and on foam (ratio ankle muscle/ paraspinal muscle control= 0.86) ($F(1,46)= 61.21$, $p<0.0005$) compared to both the healthy young and middle-aged individuals (respectively, 0.64 and 0.48).
Conclusions: Compared to persons with recurrent LBP both young and middle-aged healthy persons have the flexibility to switch postural control strategy depending on the requirements of changing postural condition, such as standing on an unstable support surface. Persons with recurrent LBP, however, seem to show no variability in postural control strategy. Using ankle strategy (and stiffening of all body segments) might be effective in simple conditions, however, when used in all postural conditions this could be a mechanism to undue loading of the spine, pain and recurrences. References Brumagne S, Cordo P, Verschueren S. Proprioceptive weighting changes in persons with low back pain and elderly persons during upright standing. Neurosci Lett 2004;366:63-66.

WP-5

Postural posteffects following foot sole stimulation

R. Roll, A. Kavounoudias and J. Roll

Laboratoire de neurobiologie Humaine UMR 6149, CNRS-Université de Provence, marseille cedex 03, France

Introduction: The so called "Kohnstamm phenomenon" (1915) or motor posteffect has been described as an involuntary movement of a subject's arm or leg occurring after a strong isometric contraction was maintained for several seconds in these limb muscles. Since these princeps observations, various studies have shown that motor posteffects may take place at various body levels including the whole-body after muscle mechanical vibrations as well (Wierzbicka et al 1998; Duclos et al 2004; Kluzik et al 2005). Interestingly, we demonstrated recently that oriented postural responses may also be induced by short-duration vibration of plantar mechanoreceptors (Kavounoudias et

al 1999; Roll et al 2002). Therefore, our objective was to investigate whether motor post-effects developped involuntarily following the sustained stimulation of the foot soles of a standing subject.
Methods: For this purpose, we applied a 30s tactile stimulation to either right or left sole of unmoving and blindfolded subjects by means of a 60 micro-vibrator tactile matrix set in a force platform. The effects of the prolonged stimulation were assessed through seven stabilometric recordings following the stimulation with one min rest interval between.
Results: Results showed that all subjects exhibited whole-body leanings mainly oriented in the frontal plane according to the stimulation side and which lasted 15 min at least. The postural posteffects decreased progressively from the first up to the seventh test; however, in most subjects they did not disappear totally after the last test.
Conclusions: Data are interpreted as an adaptive recalibration of the postural reference altered by the increased cutaneous input from the foot soles. They confirm the proprioceptive functional role of the tactile plantar information and its contribution to the coding and the spatial representation of the body posture. The generalization of the Kohnstamm effect to the tactile sensory modality is discussed.

WP-6

Balance control is more severely affected in Sensory Neuron Disease (SND) than in diabetic polyneuropathy

A. Nardone[1], M. Galante[1], M. Godi[1], M. Grasso[1] and M. Schieppati[2]

[1]Division of Physical Therapy and Rehabilitation, Fondazione Salvatore Maugeri, Veruno (Novara), Italy and [2]Department of Experimental Medicine, University of Pavia, Pavia, Italy

Introduction: Proprioception and vision play a major role in balance control: hence, patients with peripheral neuropathy are unstable when standing with eyes closed. Instability is further impaired in diseases in which the centripetal branch of the dorsal ganglion cells in also affected, as occurs in SND.
Methods: We have recruited 21 normal subjects (N), 14 patients with diabetic polyneuropathy (DP) and 11 with SND. Body sway area (SA) under quiet stance was measured through a stabilometric platform, with eyes open (EO) and closed (EC). To assess balance under predictable dynamic condition, subjects were asked to stand with EO and EC on a platform producing continuous horizontal sinusoidal (0.2 Hz) translations in the antero-posterior direction. Unexpected perturbations consisting of toe-down or toe-up rotations of a supporting platform evoked respectively a segmental medium-latency EMG response (MLR) and a supraspinal long-latency response (LLR) in tibialis anterior (TA) muscle.
Results: Clinical and neurophysiological evaluation revealed a more severe motor impairment in patients with DP than SND, while sensory impairment was superimposable. SA during quiet stance was larger in SND than DP patients, both with EO and EC. When balancing on the continuously moving platform, SD of head displacement was only little increased in DP patients with respect to N under both visual conditions. On the contrary, SND patients swayed to a significantly larger extent than DP under both visual conditions. The latency of TA MLR during unexpected platform rotations was increased in SND. The latency of TA LLR was further increased, in keeping with degeneration of centripetal branch of sensory fibres. In the SND patients, sway was larger the longer the latency of TA MLR. Those patients showing the most increased TA LLR latency were unable to stand EC.
Conclusions: Balance control is greatly deranged in SND compared to DP patients, in spite of a lesser motor impairment. The changes in latency of TA MLR suggest that the severe impairment of balance in SND partly depends on changes in excitability of spinal reflex circuits fed by impaired peripheral afferent fibres. In addition, the major balance abnormalities in SND may also depend on abnormal supraspinal integration of proprioceptive input, as indicated by the inability to stand with EC in those patients with disproportionately long TA LLR latency. The degeneration of the centripetal axonal branches of the dorsal ganglion cells in SND may change the excitability of brainstem centres responsible for balance control.

Biomechanics 2

WP-7

Bilateral coordination of stepping while walking along a straight line or a circle in healthy adults

M. Plotnik[1], R. Bartsch[2], M. Leshem[3], N. Giladi[1], S. Havlin[2] and J.M. Hausdorff[1]

[1]Movement Disorders Unit, Tel Aviv Sourasky Medical Center, Tel Aviv, Israel, [2]Physics, Bar Ilan University, Ramat Gan, Israel, [3]Biomedical Engineering, Tel Aviv University, Tel Aviv, Israel, [4]Neurolgoy, Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel, [5]Physical Therapy, Sackler School of Medicine, Tel Aviv University, Tel Aviv, Israel and [6]Division on Aging, Harvard Medical School, Boston, MA, USA

Introduction: Mechanisms responsible for bilateral coordination of gait in man are not fully understood. For example, patients with Parkinson's disease (PD) who suffer from freezing of gait (FOG) have reduced ability to coordinate left/right stepping. Inexplicably, these patients frequently freeze when challenged with turns. In this study, our objective is to understand the effect of turning on the level of bilateral coordination of stepping in healthy young adults.
Methods: We examined the gait of young adults (n=12; ages: 23-30 yrs, 5 males) with right side dominancy. Subjects wore force sensitive insoles which recorded the timing of the events within each gait cycle. Subjects continuously performed different types of walking (each of 50 m length) in the following order: (1) Straight line walking; (2) Circular walking (radius = 4m) - right side inward; (3) as in (1); (4) Circular walking - left side inward; and (5) as in (1). For each subject, gait speed was recorded. Swing time (the time a foot is in the air) was calculated and averaged across strides for the left and right feet (SWL and SWR). Gait asymmetry (GA) was defined as: $|\ln(SWR/SWL)|$. Stride-to-stride variability was defined as the coefficient of variation (CV) of the stride time. In addition, 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 CV of ϕ and the mean absolute difference between ϕ and 180° was defined as the Phase Coordination Index (PCI), representing variability and inaccuracy, respectively, in phase generation.
Results: No fatigue effect was observed as all straight line walking produced similar values of gait parameters. When turning in a circle, either direction, gait speed remained similar to that recorded during straight line walking. CV, GA and PCI were significantly increased while turning. GA was significantly increased in turns with the left leg as the inner leg as compared to the right leg as the inner leg. See the table for more details.
Conclusions: In healthy subjects, left/right coordination of stepping becomes more variable and less consistent when walking along a circular trajectory. Gait variability and GA increase as well, but the effect of circular walking on GA depends on side dominance. Extrapolating from these results, we speculate that the increased demand on the level of bilateral coordination during turning may contribute to the difficulty that patients with PD have with this commonplace task.
Means (SE) values of CV, PCI and GA

Type of gait	Speed (m/s)	CV (%)	GA	PCI (%)
Straight line walking	1.37 (0.03)	1.47 (0.07)	1.35 (0.22)	2.33 (0.09)
Circular walking -left	1.36 (0.03)	1.99* (0.17)	5.11* (0.77)	3.43* (0.31)
Circular walking -right	1.37 (0.04)	1.85* (0.11)	3.57*# (0.70)	3.03* (0.29)

*Significant difference re straight line walking ($p<0.05$); #Significant difference re circular walking - left ($p<0.05$)

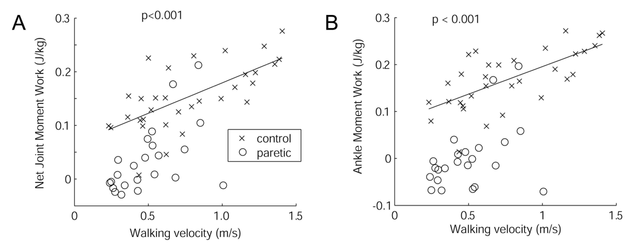
WP-8

Joint moment work during the stance-to-swing transition in hemiparetic subjects

G. Chen and C. Patten

Rehabilitation R&D Center, VA Palo Alto Health Care System, Palo Alto, CA, USA

Introduction: After suffering a stroke many individuals are left with neurological and functional deficits, including hemiparesis, which impair their ability to walk. Our previous work reported that propulsion of the paretic leg during pre-swing is impaired, which may limit gait speed and knee flexion during swing. To elucidate the mechanism of this impairment, we assessed the mechanical work produced by the hip, knee, and ankle moments during pre-swing of the paretic limb in a group of stroke subjects and compared it with the work produced by non-disabled controls walking at similar speeds.
Methods: Kinematic and kinetic gait data were collected from 23 stroke and 10 control subjects. The stroke subjects walked at their self-selected speeds. The controls walked at their self-selected and two or three slower speeds. In the stroke subjects, joint moment work at the hip, knee, and ankle were computed during pre-swing of the paretic limb, the period from foot contact of the non-paretic limb to foot off of the paretic limb. In the controls, joint moment work were computed during pre-swing of both limbs and averaged. Linear regression models were fitted to the control data with hip, knee, ankle, and net joint moment work as the dependent variables and walking speed the independent variable. A non-parametric sign test was used to test the differences between the stroke data and the expected values in controls based on the regression models.
Results: In the stroke subjects, net joint moment work during pre-swing of the paretic limb was significantly reduced (-0.087 ± 0.054 J/kg, $p<0.001$, see Figure A). The reduction was due entirely to reduced ankle plantarflexor work during pre-swing (-0.136 ± 0.061 J/kg, $p < 0.001$, see Figure B). Differences in hip and knee moment work (0.009 ± 0.020 and 0.040 ± 0.027 J/kg, $p = 0.035$ and $p < 0.001$, respectively) partially compensated for the reduction in ankle moment work, but net work was still significantly reduced.
Conclusions: Even when compared to controls walking at slow speeds, ankle plantarflexor and net joint moment work during pre-swing were greatly reduced in the stroke subjects. The reduction in work accounts for the low energy of the paretic limb at the stance-to-swing transition previously reported. Other investigators have suggested that large hip flexion moments during pre-swing can compensate for plantarflexor weakness in stroke subjects. Our study found that differences in knee moment work can also partially compensate for reduced plantarflexor work.



WP-9

Muscle contributions to trunk and leg propulsion with increasing walking speed

R.R. Neptune[1], K. Sasaki[1] and S.A. Kautz[2]

[1]*Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX, USA and* [2]*Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA*

Introduction: Previous analyses of young adults walking at their self-selected speed has revealed that the hip and knee extensors act to brake the trunk in early stance and ankle plantar flexors and rectus femoris act to accelerate the trunk in late stance [1, 2]. In addition, the gastrocnemius and hip flexors generate energy to the leg in pre- and early swing to provide leg swing. However, how the muscles' putative contributions to these functional tasks change with walking speed is not well understood. The purpose of this study was to examine how muscles contribute to the trunk and leg energetics as walking speed increases using muscle-actuated forward dynamics simulations that emulate experimentally collected data across increasing speeds.
Methods: An existing sagittal-plane musculoskeletal model and dynamic optimization framework [1] was used to generate forward dynamics simulations of walking at five different speeds (0.4, 0.8, 1.2, 1.6 and 2.0 m/s). The simulations were generated by solving the optimal tracking problem, which identified the individual muscle coordination patterns such that the simulations emulate experimentally collected ground reaction force

and body segment kinematic data from 10 healthy subjects. Individual muscle contributions to the mechanical power of the trunk and leg segments were quantified using a segment power analysis [3].
Results: As walking speed increased, muscle contributions to trunk braking (mechanical power absorbed from the trunk) by the hip and knee extensors in early stance and propulsion (power generated to the trunk) by the plantar flexors and the rectus femoris in late stance systematically increased. The largest muscle adaptation with walking speed occurred in the hip flexors, as they generated greater mechanical power to the leg to facilitate swing.
Conclusions: The systematic increase in muscle contributions to trunk and leg mechanical power was consistent with previous EMG measurements [4]. Increasing walking speed has been shown to be associated with longer stride lengths [5], which leads to greater braking by the hip and knee extensors. The increased braking subsequently requires greater propulsion by the plantar flexors and rectus femoris in late stance. Increased stride lengths also requires increased power generation from those muscles contributing to leg swing, which occurred primarily in the hip flexors. These results provide important insight into the neuromotor mechanisms underlying speed regulation in walking and provide the foundation on which to investigate walking speed in various pathological populations. **References:** [1] Neptune et al. (2004). Gait Posture. 19: 194-205. [2] Zajac et al. (2003). Gait Posture. 17: 1-17. [3] Fregly and Zajac (1996). J Biomech. 29: 81-90. [4] Hof et al. (2002). Gait Posture 16: 78-86. [5] Holden et al. (1997). Clinical Biomechanics 12: 375-382. **Acknowledgements:** Funding was provided by the Whitaker Foundation and NIH grant R01 HD46820.

WP-10

Gait speed modulation is limited by impaired hip and ankle power generation in lower functioning persons post-stroke

I. Jonkers[4], S.L. Delp[3] and C. Patten[1]

[1]Rehabilitation R&D Center, VA Palo Alto HCS, Palo Alto, CA, USA, [2]Orthopaedic Surgery, Stanford University, Stanford, CA, USA, [3]Biomedical Engineering, Stanford University, Stanford, CA, USA and [4]Biomedical Kinesiology, Katholike University, Leuven, Belgium

Introduction: Limited walking speed characterizes gait post-stroke. Modulation of gait speed is also impaired, limiting adaptation to environmental conditions. Gait speed modulation has not been thoroughly investigated in persons post-stroke. This study makes a unique contribution by comparing the mechanisms to increase gait speed in hemiparetic persons demonstrating both higher and lower levels of locomotor function. These observations are compared to control subjects walking at matched speeds. We hypothesize that impaired recruitment of paretic side hipflexor and plantarflexor muscles limits the potential to increase gait speed in lower functioning hemiparetic subjects.
Methods: Instrumented gait analysis was used at self-selected and fast walking conditions in 12 persons with post-stroke hemiparesis. Two groups were identified: 1) lower functioning subjects (LFH, n=6) who increased gait speed normalized for leg length (ll) from 0.52 ll/s (SEM: 0.04) to 0.72 ll/s (SEM: 0.03) and 2) higher functioning subjects (HFH, n = 6) who increased gait speed from 0.88 ll/S (SEM:0.04) to 1.4 ll/s (SEM 0.03).
Results: Changes in spatiotemporal parameters, joint kinematics and kinetics between self-selected and fast gait were compared to speed-matched control data (0.35 ll/s (SEM: 0.03) - 0.63 ll/s (SEM: 0.03) - 0.92 ll/s (SEM: 0.04) and 1.4 ll/s (SEM: 0.04)). To increase gait speed, HFH-subjects increase paretic limb plantarflexor power generation (A2, average increase of 55% compared to 95% in speed-matched controls) and hipflexor generation (H3, average increase of 41%compared to 31% in speed-matched controls). In contrast, LFH-subjects demonstrate failure to increase power generation at the paretic ankle (A2 - average increase of 14% compared to 30% in the speed-matched controls) coupled with a minor increase of the already-excessive paretic limb hipflexor power generation (H3 - average increase of 5% compared to 10% in the speed-matched controls).
Conclusions: Mechanisms observed in HFH-subjects correspond to previous findings (Nadeau, 1999; Milot, 2006) indicating that hemiparetic subjects preferably engage hipflexor power generation to compensate for plantarflexor muscle weakness. However, impaired ankle power generation combined with saturation of hipflexor power generation limits the potential to modulate gait speed in LFH-subjects. Rehabilitation interventions to improve gait speed should therefore target enhancing power generation of both ankle plantarflexors and hipflexors.

	Paretic SS	Paretic FAST	Sig.	Non-paretic SS	Non-paretic FAST	Sig.
H3 (Watts/Kg)						
Control HFH Sig.	0.33 ± 0.07 0.24 ± 0.07 ns	0.63 ± 0.06 0.72 ±0.25 ns	** *	0.31 ± 0.03 ns	0.85 ± 0.25 ns	°
Control LFH Sig	0.12 ± 0.01 0.21 ± 0.07 °	0.16 ± 0.03 0.26 ± 0.04 °	° ns	° ns	0.31 ± 0.03 **	°
A2 (Watts/Kg)						
Control HFH Sig.	1.46 ± 0.11 1.22 ± 0.3 ns	2.41 ± 0.13 1.7 8 ± 0.51 ns	** °	** ns	2.57 ± 0.55 ns	ns
Control LFH Sig	0.59 ± 0.07 0.29 ± 0.07 *	0.89 ± 0.07 0.44 ± 0.08 **	** ns	1.42 ± 0.24 *	0.86 ± 0.29 ns	ns

o p<.1

* p<.05

**p<.01

WP-11

Effects of stance width on postural movement pattern and anticipatory postural control associated with unilateral arm abduction

K. Fujiwara, H. Tomita, H. Asai, N. Kurokawa and K. Maeda

Graduate School of Medical Science, Kanazawa University, Kanazawa, Ishikawa, Japan

Introduction: It is well known that structural stability of lower limbs in standing human increases according to stance width. We investigated effects of stance width on postural movement pattern and anticipatory postural control associated with unilateral arm abduction.
Methods: Subjects were 32 healthy adults, aged 19-42 years (mean 23.9 ± SD 6.7). Subjects abducted the right arm at their own pace, and then stopped the arm at a horizontal level. Subjects were told to move their arm at near maximum speed. Stance width was set at 0, 9, 18, and 27 cm. The arm abduction was repeated 10 times at each stance width. In order to measure postural movement pattern during arm abduction, a high-speed camera was placed 5.5 m behind of the subjects. Small reflective markers were placed

over the vertebra prominens, the median sacral crest, and at the midpoint between both heels. Based on the positions of the markers at 150-300 ms before the start of arm movement and at the end of arm movement, leg inclination angle (median sacral crest - midpoint between both heels) and leg-trunk angle (vertebra prominens - median sacral crest - midpoint between both heels) were measured. Then, movement angles between the two time points were calculated. Postural movement patterns were categorized based on the constant movement angles of the leg inclination and the leg-trunk into three types: body contralateral leaning type (BCL: pelvis and trunk move leftward after right arm abduction), trunk contralateral flexion type (TCF: pelvis moves rightward and trunk leftwrd), and trunk ipsilateral flexion type (TIF: pelvis moves leftward and trunk rightward). Electromyograms were recorded from elector spinae (ES), gluteus medius (GM), tensor fascia latae (TFL) on the both sides, and middle deltoid (MD) on the right side. Subsequently, burst onset timing of the postural muscles with respect to MD was analyzed.
Results: In the 0-cm stance width, the proportion of subjects was 53% in the BCL type, 25% in the TCF type, and 22% in the TIF type. According to the increase in stance width, the TIF type changed to the BCL type, while the BCL type exhibited significant decrease in leg inclination angle. Similarly, changes in movement angles were small in the TCF type. In the TIF type in the 0-cm stance width, insignificant precedence of left-side GM and TFL were exhibited, while in every distance in BCL and TCF type, significantly preceding activations were shown. On the other, the TCF type showed significantly preceding activation in right-side TFL.
Conclusions: In the 0-cm stance width, large individual difference was observed for postural movement pattern. According to the increase in stance width, movement angle in the lower limbs decreased, and the trunk flexion contralateral to the arm movement became main. In corresponding with the change, preceding activations of GM and TFL became prominent.

WP-12

Balance differences between athletes experiencing positive and negative feedback

D. Williams and B.M. Baucom

Physical Therapy, East Carolina University, Greenville, NC, USA

Introduction: Most athletes experience positive feedback during sport while others (surfers, skateboarders and snowboarders) must respond to negative feedback. Negative feedback is defined as the surface moving in the opposite direction as the athlete's sway (i.e. a slip). The purpose of this study is to compare the postural responses of non-athletes (NA), stable surface athletes (SS), and negative surface athletes (NS). We hypothesize that due to experience in a negative feedback environment, the NS will demonstrate better balance as evidenced by the least excursion of the COM when compared to the other groups.
Methods: 24 subjects (18-28 yrs) participated and were placed into 3 groups: NA (n=8), SS (n=8) and NS (n=8). Balance was estimated using the Neurocom Research System consisting of 2 moving force plates imbedded in a raised platform. Subjects attempted to maintain balance in 7 conditions: static, medial/lateral motion (+ and - COM feedback), anterior/posterior motion (+ and - COM feedback), forward/backward tilt (+ and - COM feedback). Data was analyzed by averaging (5 trials) the integral of the excursion of the COM from the center of pressure. A MANOVA ($p \leq 0.05$) was employed to compare groups. Post-hoc t-tests determined differences in specific conditions.
Results: Significant differences were found between athletes (Table 1). Between SS and NS, greater excursion was seen in NS during negative feedback trials. Between NS and NA, greater excursion was seen in NS across all conditions, all directions, and all feedback including stable trials. Between SS and NA, greater excursion was seen in SS in the positive direction (static and dynamic) and decreased lateral excursion in medial-lateral movement with negative feedback.
Conclusions: In contrast to our hypothesis, NS showed more excursion of the COM in most conditions, especially those in the medial/lateral direction. Greater excursion of the COM in NS when compared to SS suggests better balance when perturbed with negative feedback due to familiarity with this activity during their sport. Greater excursion in NS compared to NA suggests better balance in the NS regardless of condition. Greater excursion in SS compared to NA in positive feedback trials may suggest SS are more comfortable and have better balance than NA. However, decreased lateral excursion in SS in medial-lateral movement with negative feedback suggests that although they may not be comfortable with this condition, they attempted to stabilize more than NA. These data suggest that NS show improved balance in negative and positive feedback environments compared to SS and NA.

Table 1: p-values for selected variables

	+AP(x)	-AP(y)	+ML(x)	+ML(y)	-ML(x)	-ML(y)	Static(x)	+TILT(x)	-TILT(x)	-TILT(y)
SS vs. NS	0.052	0.025	0.125	0.004	0.004	0.001	0.141	0.080	0.008	0.048
SS vs. NA	0.012	0.497	0.033	0.155	0.120	0.014	0.015	0.029	0.102	0.112
NS vs. NA	0.051	0.020	0.003	0.001	0.030	0.212	0.001	0.074	0.186	0.008

+/- =feedback direction. ML/AP/TILT =motion of plate. x/y =COM from plate.

WP-13

Muscle contributions to body support and forward propulsion during toe walking

K. Sasaki[1], R.R. Neptune[1], J.M. Burnfield[2] and S.J. Mulroy[3]

[1]Department of Mechanical Engineering, The University of Texas at Austin, Austin, TX, USA, [2]Institute for Rehabilitation Science and Engineering, Madonna Rehabilitation Hospital, Lincoln, NE, USA and [3]Rancho Los Amigos National Rehabilitation Center, Downey, CA, USA

Introduction: Toe walking is a gait deviation associated with various musculoskeletal and neurological disorders. An important clinical problem is to distinguish between underlying pathology and necessary compensatory mechanisms in order to determine the most appropriate treatment. Previous studies of toe walking in able-bodied subjects found that the peak ankle moment during early stance is greater than that in heel-toe walking [1, 2]. In contrast, ankle moment and power during late stance were found to be lower than those in heel-toe walking [1, 2]. These changes are significant since the plantar flexors are not normally active in early stance and are the primary contributors to body support and forward propulsion in late stance [3].

These findings suggest that other muscles may have to compensate to provide the necessary body support and propulsion. The purpose of this study was to quantify how muscle contributions to body support and forward propulsion are altered in toe walking relative to heel-toe walking.
Methods: A sagittal-plane musculoskeletal model was generated using SIMM (MusculoGraphics Inc.) and the equations of motion were generated using SD/FAST (PTC). Muscle excitation patterns (11 muscle groups per leg) were fine-tuned using an optimization algorithm such that the simulation kinematics and ground reaction forces (GRFs) closely matched corresponding experimental data. The experimental data were obtained from 10 able-bodied subjects during both toe and heel-toe walking at the same speed [2]. Individual muscle contributions to body support (vertical GRF) and forward braking/propulsion (horizontal GRF) were identified using a ground reaction force decomposition technique [3].
Results: Soleus contributions to body support and braking increased substantially during early stance in toe walking. These increased contributions were concomitant with decreased contributions to support from the vastii and gluteus maximus muscles relative to heel-toe walking, and decreased braking contributions from the vastii muscles. During late stance, the soleus contributed less to body support and forward propulsion in toe walking. To compensate for the decreased propulsion by the soleus, the hamstrings increased their contribution to forward propulsion from mid- to late stance.
Conclusions: Toe walking requires multiple compensatory mechanisms in order to generate necessary body support and forward propulsion, which have important implications for distinguishing underlying pathology from necessary compensation and for determining the most appropriate treatment strategy for equinus gait. References [1] Kerrigan, D.C. et al. (2000). Arch Phys Med Rehab. 81: 38-44. [2] Perry, J. et al. (2003). Arch Phys Med Rehab. 84: 7-16. [3] Neptune, R.R. et al. (2004). Gait & Posture. 19: 194-205.

WP-14

Gait variability after a stroke and its relationship to hemiparetic severity and walking balance

C. K. Balasubramanian[1], M.G. Bowden[2], R.R. Neptune[3] and S.A. Kautz[2]

[1]Physical Therapy, University of Florida, Gainesville, FL, USA, [2]Brain Rehabilitation Research Center, North Florida/South Georgia Veterans Health System, Gainesville, FL, USA and [3]Mechanical Engineering, University of Texas, Austin, TX, USA

Introduction: Variability in spatiotemporal (ST) parameters of steps is reported to be altered in impaired gait. This altered gait variability has been related to risk for falls. However, direction of the alteration (increased or decreased variability) is not consistent between ST parameters, across impaired populations and across walking conditions. Specifically, in a stroke population it is not known whether increased or decreased variability in ST parameters is related to better walking performance. Thus, purpose of this study was to characterize variability in selected ST parameters in a stroke population during overground gait. Relationship between gait variability, hemiparetic severity and walking balance was also investigated to understand how gait variability related to walking performance. We hypothesized that hemiparetic subjects would show increased gait variability compared to healthy controls and increased variability would relate to both hemiparetic severity and walking balance.
Methods: 17 healthy and 20 hemiparetic subjects walked for 3 trials at their self-selected speed over an instrumented mat (GAITRite) and ST parameters were collected. Selected parameters (stance time, swing time, step length and step width) were analyzed. Variability in ST parameters was calculated as Coefficient of variation (SD/Mean x 100) in steps across trials. Lower extremity Fugl-Meyer (FM) scale assessed hemiparetic severity and Dynamic Gait Index (DGI) scale assessed walking balance. One-way ANOVA with three levels (control, paretic, nonparetic leg) examined differences in variability between control and hemiparetic subjects and was followed-up by Bonferroni's tests. Correlation analyses related ST variability to FM and DGI scores.
Results: ANOVA was significant for all comparisons ($p < .01$). Post-hoc tests showed that both paretic and nonparetic leg variability were significantly greater than control leg ($p < .05$) but there was no difference between paretic and nonparetic leg variability. Correlation analyses showed that FM and DGI scores inversely related to variability in all ST parameters (though not all relations were significant) and that variability between ST parameters were inter-related. Therefore, a stepwise regression model was conducted to choose the single best predictor of severity and balance out of all ST parameters. The model chose stance time variability as best predictor of severity (ρ= -.62, p=.005) and step width variability as best predictor of balance (ρ= -.59, p=.008).
Conclusions: Variability in specific ST parameters increased in persons with stroke compared to healthy controls while walking overground at self-selected speed. Severity and balance scores were inversely related to variability in ST parameters (though not all relations were significant), indicating that more severe subjects and those with poor balance had increased gait variability. Specifically, variable stance time strongly related to severity and variable step width related to poor walking balance.

WP-15

The effects of foot placement on able-bodied and FES-assisted quiet standing

J.C. Gillette and C.A. Stevermer

Health and Human Performance, Iowa State University, Ames, IA, USA

Introduction: Functional electrical stimulation (FES) systems have provided individuals with spinal cord injuries (SCI) varying capability to stand. Stable quiet standing with limited hand support is a prerequisite to using FES for activities of daily living such as reaching at a counter. Previous studies have found that postural responses and motor control strategies were dependent upon foot placement. Therefore, foot placement may be a useful preparatory adjustment to achieve a favorable base of support. The goal of this study was to compare center of pressure (COP) parameters between able-bodied and FES-assisted quiet standing. It is anticipated that the results will be useful in design and training guidelines for FES users.

Methods: Two subjects with SCI were case studies. FES user #1 was 38 years old, had a T6 level injury (ASIA-A), and used an Octostim for surface stimulation of the quadriceps, hamstrings, and gluteals. FES user #2 was 32 years old, had a T4/T5 level injury (ASIA-A), and used an implanted CWRU/VA system to stimulate the gluteus maximus, posterior adductor, vastus lateralis, and erector spinae muscles. FES users stood at parallel bars with minimal hand support. Seventeen subjects (9 male/8 female, age 32.2 ± 5.4 yrs) participated as an able-bodied comparison. Subjects quietly stood for 30 s using normal (ASIS width), wide (twice normal width), and staggered (ASIS width, dominant foot shifted one foot length forward) foot placements. FES users stood twice with each foot placement on four separate days (24 trials), while able-bodied subjects stood three times with each foot placement (9 trials). Each foot was placed on a force platform to measure changes in COP.

Results: FES user #1 averaged 21.1% and FES user #2 averaged 10.5% body weight hand support. Maximum medial/lateral (M/L) COP velocities were higher for FES users with normal (FES#1 72.7, FES#2 116.5, able-bodied 20.5 ± 7.1 mm/s), wide (FES#1 84.1, FES#2 181.6, able-bodied 27.6 ± 8.5 mm/s), and staggered (FES#1 97.0, FES#2 133.7, able-bodied 47.8 ± 17.1 mm/s) placements. Similarly, maximum anterior/posterior (A/P) COP velocities were higher for FES users with normal (FES#1 83.6, FES#2 99.0, able-bodied 34.9 ± 14.9 mm/s), wide (FES#1 78.6, FES#2 88.2, able-bodied 38.4 ± 14.4 mm/s), and staggered (FES#1 72.4, FES#2 126.0, able-bodied 58.4 ± 23.0 mm/s) placements. FES users also averaged more anterior A/P COP origins, more asymmetrical M/L COP origins, and greater M/L COP excursions.

Conclusions: FES users displayed the greatest differences from able-bodied individuals in the M/L direction. One explanation is the focus on stimulating muscles with extensor torques, which act primarily in the A/P direction. In addition, higher COP velocities in both the A/P and M/L directions may be due to postural adjustments via hand support being less sensitive and more abrupt. Of those tested, the staggered placement provided the closest match of COP parameters between FES users and able-bodied individuals.

WP-16

Trailing leg postural strategies during slipping

R. Cham, B. Moyer and M.S. Redfern

Bioengineering, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: Same-level falls precipitated by slipping are among the leading causes of disability in the elderly. Legs, trunk and arms all contribute to the complex slip-initiated postural response. While the response of the leading leg, i.e. slipping leg, has been previously described [1], a precise characterization of the trailing leg strategies is lacking and this information is important to understand the human factors contributing to the increased risk of slips/falls in older adults. Thus, the goal of this study is to identify the trailing leg postural strategies during slipping, and to investigate whether these strategies are coordinated with the leading leg response.

Methods: Thirteen older (55-67 years old) and 15 younger (20-33 years old) healthy subjects participated in this gait study. To ensure natural walking, participants were informed that the first few trials would be non-slippery. Two or three dry trials were collected ("baseline"). Then, without the participant's knowledge, a glycerol solution was applied onto the floor and another gait trial was conducted ("unexpected slip"). Full body motion and bilateral ground reaction forces were collected. A custom-developed 15 segment whole body model was utilized to derive joint angles and moments using inverse dynamics approaches.

Results: Four strategies termed minimum (MIN), foot-flat (FF), mid-flight (MID), and toe-down (TD) were identified based on the trailing foot flight distance/duration and the trailing foot orientation upon contact with the floor. MIN patterns are the least severe slips and TD responses are the most severe slips ($p = 0.01$). A statistically significant correlation was found between the type of trailing leg strategy and the moment generated by the knee of the leading leg during slipping ($p < 0.01$). Specifically, a reduced extension moment at the knee of the leading leg during slipping appears to be correlated with a greater risk of responding with a TD pattern. Also, subjects who normally (known dry environments) walk with a reduced extension hip moment in the stance leg at contralateral toe off experienced a toe down slip pattern when the floor was contaminated ($p < 0.01$). Finally, age group effects were not statistically significant.

Conclusions: Thus, trailing leg strategies appear to play an important role in slip-initiated recovery responses. The findings of this study suggest the selection of trailing leg strategies depend both on the response generated by the leading leg after a slip is initiated but also on typical normal walking patterns on dry floors. No age effects were found in this study, perhaps because the older group of participants was healthy and not very old. However, the results also suggest that motor responses that may be affected by aging, e.g. walking with a reduced knee/hip extension moment, may aggravate the risk of experiencing a TD slip pattern (most severe slip). —References [1] Cham R, Redfern MS; J Biomech 34:1439-45, 2001. —Funding source: NIOSH R03 OH007533 & R01 OH007592.

WP-17

Expression of emotion changes gait kinematics

M. Gross[1], E. Crane[1] and B. Fredrickson[2]

[1]*Movement Science, University of Michigan, Ann Arbor, MI, USA and* [2]*Psychology, University of North Carolina, Chapel Hill, NC, USA*

Introduction: Emotion is expressed through multiple physiological channels including voice, facial expression, body movements, autonomic responses and subjective experience. A biological basis for bodily expression is suggested by cross-cultural studies in which emotion is recognized in body movements (Hejmadi 2000). Typically, the effects of emotion on body movement have been studied in actors portraying emotions, and the emotion-related effects have been described only qualitatively, e.g., "heavy-footed" for angry gait (Montepare, 1987). The purpose of this study was to quantitatively describe the effect of felt emotions on gait kinematics.

Methods: Seventeen undergraduates (11 female, 6 male; 18-28 yrs) recalled an experience from their own lives in which they

felt angry, sad, content, joy or no emotion at all. After recalling an emotion, participants walked across the lab (5 m) while video and motion capture data were acquired. After each trial participants rated the intensity of 8 emotions using 5-item Likert scales. Trials in which participants felt the target emotion with at least moderate intensity were included in the recognition analysis. To determine whether the walkers' felt emotions were recognizable in their body movements, video clips of the walkers (with blurred faces) were randomized and were shown to 30 other undergraduates (15 female, 15 male; 20.9±2.5 yrs). After viewing each video clip, observers selected one of 10 emotions that they thought the walker experienced during the trial. A mixed effects regression model was used to determine the random effects of walker and observer and the fixed effects of view, emotion, walker gender, observer gender, and video sequence on emotion recognition. Joint angle data from the recognized trials (>10% agreement) served as input to the statistical analysis. A factor analysis was performed using principal components analysis to extract the factors from the original 21 kinematic variables. A Varimax rotation was applied to the factor solution to aid in interpretability of the factors. The emotions were compared in terms of means and standard deviations on the factor scores.
Results: Self-report data indicated that the walkers felt the target emotions at moderate or greater intensity in all trials. Mean recognition rates for sad, anger, joy, content and neutral trials were 43%, 22%, 20%, 19% and 25%, respectively. The first 7 principal components accounted for 76% of the kinematic variability. Rotated loadings for the principal components were significantly different among the emotions ($p<0.001$). Emotions produced characteristic changes in gait kinematics; e.g., sad gait was associated with increased neck flexion, trunk flexion, knee extension and shoulder elevation and decreased hip, shoulder, elbow and wrist flexion and shoulder abduction.
Conclusions: Bodily expression of felt emotions was associated with recognizable, emotion-specific changes in gait kinematics.

WP-18

The transition from a closed to an open kinetic chain exercise: A modeling perspective

O. Ritman[1] and N. Benjuya[2]

[1]Biomedical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel and [2]Biomechanics Lab., Kaye College of Education, Beer-Sheva, Israel

Introduction: It has been reported that triathletes experience a loss of coordination during the transition from cycling to running. When researching this phenomenon, Hodges and Chapman 1 detected an altered EMG pattern of the tibialis anterior (TA). This pattern was found to be similar to the typical EMG pattern of cycling, showing that cycling has a direct influence on the subsequent running activity. During transition between the activities, the movement is not optimally controlled by the central nervous system (CNS). Under such conditions, the athlete is more susceptible to injuries. Objective: By finding the parameters that influence the adaptation phase between the two tasks, we aim to gain a better understanding of the CNS, and how it copes with a transition from a closed to open kinetic chain exercise.
Methods: A model based on typical ground reaction force (GRF) was adapted to the MATLAB. Four untrained subjects were instructed to perform 30 min. of cycling immediately followed by running for 300 m. Trials were repeated similarly, both in indoors and outdoor conditions. GRF measurements were used as input, while the location of the leg's center of mass (COM) was used as the output of the model. By extracting data from the experimental trials, the stiffness and damping parameters were calculated. The updated model, adjusted with the newly found parameters, was then used to simulate a transition response. Output COM signals from the model were wavelet analyzed, providing the simulated adaptation time. This period was compared to the actual period analyzed from the EMG measurements taken from the unilateral shank muscles, lateral hamstring (LH), rectus femoris (RF), TA and lateral head of gastrocnemius (GAS).
Results: Preliminary results show a clear difference in the stiffness and damping parameters during the transition from cycling to running. EMG data analysis exhibited a clear adaptation phase, although varied between muscles and tasks. The LH did not exhibit adaptation in either one of the subjects. Running on different surfaces produced different degrees of leg stiffness for the same runner. In the outdoor session the RF showed a transition period for all subjects. In the indoor sessions the muscle that showed the most adaptation in all subjects was the TA.
Conclusions: Since it is not yet clear exactly how the CNS controls stiffness internally, the only manner we can intervene is by external devices with certain stiffness and damping properties. This will allow us to achieve optimal parameters that will produce a minimum adaptation period, a period where the athlete is more vulnerable to injuries. References: 1. P. Hodges, A. Chapman: The influence of cycling on lower limb movement and muscle activation during running in triathletes. Proceedings of ISB XXth Congress, ASB 29th Annual Meeting, Cleveland, Ohio, USA, 2005.

WP-19

Use of a 1-DOF rotating platform to study the rotations of human body on horizontal plane

A. Berthoz[1], P. Cappa[2], F. Patanè[2], M. Petrarca[3], S. Rossi[2] and G. Zanelli[2]

[1]LPPA, Collège de France, Paris, France, [2]Mechanical Engineering, University of Rome "La Sapienza", Rome, Italy and [3]Paediatric Neuro-rehabilitation Division, Children's Hospital "Bambino Gesù" IRCCS, Passoscuro (Fiumicino) Rome, Italy

Introduction: The world population aged quickly: in the U.S., in 2004, the elderly (65+) represented 12.4% of the total population. Moreover in Europe (15 states) an evaluation conducted in 2003 estimated that the elderly (60+) were 22.2% of the total population and the 40.0% as regards the population aged 20-59. The 54.5% of older population requires assistance for everyday life or even medical assistance, so the improvement of the quality of life becomes a relevant task and the first investigated aspect is the capabilities of subject to maintain the postural equilibrium. In addition study focused on the posture in adults is also useful in order to determine a comparison paradigm for pathological children. Postural control is due to interaction between the passive dynamic of neuromuscolar system (McGeer,1990)

and the active control of CNS, on the basis of information collected by visual, vestibular and somatosensorial systems (Blumle,2006). Equitest (Neurocom International, Clackamas, OR) is an apparatus that is widely used to study dynamic posturography. It permits to investigate the contribution of visual, proprioceptive, somatosensory and vestibular inputs. The main limit of Equitest is the capability to study the posture only on sagittal plane, even if actual perturbations are not directed on a single axes and the postural response is sensible to multidirection perturbations (Carpenter,2001). Besides, it is also demonstrated that it is not possible to derive the postural response to a complex perturbation by the simple one (Carpenter,1999). However, to understand the importance of a perturbation on the other plane, it is possible to use the Equitest with the subject rotated of 90 deg (Allum,2002).
Methods: On the basis of the previously observations, it was decided to exploit the capability of healthy subjects to maintain the equilibrium when a moving platform applies the rotations around the vertical axes (yaw). The in-house developed apparatus is driven with an electrical motor, entirely programmable via computer so that both stationary or random rotations are imposed. The frequency for the motion is a sweep from 0.1 to 1.0 Hz and the trials will be conducted with eyes open and closed. Thus, we will examine angular rotations of the head, trunk and leg, evaluated by means of an optoelectronic system (Vicon 512) in 3D and respect to platform to understand the kinematics of the 3-link model of human body, with reference to observations made with other perturbations (Buchanan,2003).
Results: In particular, the oscillations of three districts are sinusoidal as perturbation, but with an increased lag if the district is far from the platform; instead the oscillations are bigger for the district closer to the platform. Besides, the oscillations decrease if the frequency of perturbation increases and, in particular, the oscillation of the head decreases, when the eyes is open, to stabilize the vision.
Conclusions: In conclusion, the stabilization of vision is a main task of postural control.

WP-20

Kinematic and Kinetic Changes during slow sit to stand

D. Brunt, D. Williams, D. Stewart and A. Durland

Physical Therapy, East Carolina University, Greenville, NC, USA

Introduction: Forward trunk momentum is required for successful sit-to-stand (STS). The momentum should be sufficient to achieve seat-off and place the center of mass over the feet. In addition, a braking force is required to initiate seat off and to transfer horizontal to vertical momentum. If the velocity of trunk flexion is low (frailty, Parkinson's disease) or hip motion limited (obesity, pregnancy, hip replacement) then additional assistance during STS is required or a step back failure may occur. The purpose of this study is to demonstrate changes in lower extremity kinematics and kinetics following a simple adaptation to a standard chair in healthy subjects who STS slowly.
Methods: 5 healthy male subjects (20-26 yrs) participated in the study. Retroreflective markers were placed to enable calculation of left lower extremity and pelvic motion. Subjects were asked to STS slowly and synchronize speed of ascent to a metronome at 40 beats per minute. In sitting, the knee and ankle angles were 90 degrees with the left foot on a force plate. The chair was also on a force plate to determine seat-off. Subjects completed 5 trials in each of two conditions: static posterior force (SF) applied by the lower leg to the chair at 16.25 cm below the knee joint line and no force (NF) applied by the posterior lower leg. Data were sampled at 120 Hz using a six camera motion analysis system. Force data were sampled at 960 Hz. Three dimensional positions of the tracking markers were determined. Data were analyzed from onset of movement for 3.5 secs. Dependent variables included peak ankle and hip angles, peak knee extension angle and peak horizontal and vertical ground reaction forces. Data were analyzed by a paired t-test.
Results: There was no difference in peak vertical ground reaction force (Fz) at seat off (mean=48% body weight) or peak knee angle (mean=77.4 deg) at the end of the 3.5 sec data collection. However, the amount of dorsiflexion (6.7 versus 2.1 deg, p=0.06) and hip flexion (86.5 and 75.4 deg, p=0.09) were greater for the NF group. Time to peak ankle dorsiflexion (1.79 sec and 1.26 sec) and hip flexion (1.23 sec and 0.70 sec) occurred significantly earlier for the SF group. The braking force at the feet was significantly greater for the SF condition (22% versus 1.6% body weight).
Conclusions: The rate of ascent was similar between conditions as determined by no difference in peak Fz (rate of seat off) or final knee joint angle. To achieve this ascent and final position required less dorsiflexion and hip flexion in the SF condition. Peak angles were therefore earlier in the SF condition. A major difference was the increased braking force in the SF condition. We believe this is related to the force couple generated by the posterior force of the calf against the chair and the feet on the floor. It is this force couple that allows an earlier ascent with less hip and ankle flexion to come to STS at a slow speed. Similar adaptations to chairs may assist those patients who have difficulty in STS.

WP-21

Motor control strategies involved in the task of swinging on a playground swing

N. St-Onge[1], P. McKinley[1] and J. Fung[1]

[1]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [2]CRIR Rehabilitation Center, Jewish Rehabilitation Hospital, Laval, QC, Canada

Introduction: Playground swinging contains an incremental and a maintenance component, whereby a wind-up phase occurs to attain peak amplitude, and a steady state phase occurs to maintain swing amplitude, respectively. The goals of the present study were to determine how these phases were affected by the dynamics of the starting posture, ie resting vs running start; and if the incremental (wind-up phase) and maintenance (steady state phase) components placed different demands on the neuromuscular system.
Methods: While sitting, participants were instructed to pump the swing into motion with or without a running start, and to increase the swing amplitude until comfortable steady state amplitude could be maintained. Reflective markers were placed on the swing and on body segments using the plug-in-gait marker

set to record positional changes during swinging (VICON). Electromyographic (EMG) activities from eight trunk, arm, and leg muscles were recorded using bipolar surface electrodes (Noraxon). Intersegmental and segmental angles were computed. When starting from rest, three phases were identified: start-up with small, consistent swing amplitude, wind-up where swing amplitude increased and steady state, a period where maximum amplitude was maintained. Running start trials showed only wind-up and steady state phases.

Results: Cycle amplitude increased progressively and reached a constant during the steady state; the period was greatest during start-up and decreased, but remained constant during wind-up and steady state. Regardless of start-up condition, equivalent amplitude and period values were reached by 8 cycles. Angular displacements during the wind-up and steady state phases of the running start trials were similar. In contrast, angular displacements were greater during the wind-up phase than during the steady state phase for start-at-rest trials; for start-up, there was a lag as compared to the wind-up and steady state phases; not only did trunk peak extension and flexion during the start-up phase exceed those during steady state by about 15-20°, they lagged by about 10-15% of a cycle. Variability in angular displacement was also different for the start-up phase as compared to wind-up and steady state, and with respect to placement within the cycle. EMG pattern, peak amplitude, and RMS were comparable for the wind-up and steady state phases in the running-start, but not for start-at-rest. When comparing the two conditions, the starting-at-rest EMG amplitudes were greater than those of running-start trials. Also, during the start-up phase of these trials, amplitude and RMS were increased in some muscles and decreased in others as compared to the other two phases.

Conclusions: Initial posture and movements affect the neuromotor strategies involved in the swinging task. In the start-at-rest condition, a driven oscillator is used where energy has to be put in order to move the swing, whereas in the running-start condition, potential and kinetic energy are exchanged to keep the swing moving.

WP-22

Leg length influences gait parameters at maximal velocity in sprinters of different performance levels

L.M. Decker[3], F. Natta[2] and S. Renous[1]

[1]Département d'Écologie et de Gestion de la Biodiversité, CNRS FRE 2696, Adaptations et Évolution des Systèmes Ostéomusculaires, Muséum National d'Histoire Naturelle, Paris, France, [2]Département des Sciences du Sport, Laboratoire Mouvement, Action et Performance, Institut National du Sport et de l'Éducation Physique, Paris, France and [3]HPER Biomechanics Laboratory, University of Nebraska at Omaha, Omaha, NE, USA

Introduction: Sprint running is a complex voluntary rhythmic motor behaviour. For example, a wide combination of gait parameters, such as step length and frequency, can be found in world-class sprinters. The purpose of this study was to investigate what factors affect gait parameters during sprinting in athletes with different performance levels and to examine their gait patterns by using morphological features. We specifically hypothesized that: (1) leg length will influence gait parameters differentially in sprinters of different skill levels, (2) gait parameters can be used to predict these skill levels during sprinting.

Methods: Fourty-three male sprinters with 5 extremely advanced (international level), 9 advanced (national level), 12 intermediate (regional level) and 17 novices participated in the study. They all performed two maximal-effort sprints. The running performances were evaluated by an optical acquisition system (Optojump, Microgate, Italy) for measuring the flight and contact times, step length and their positions along the track between 18- and 78-m marks of a 100-m race. We applied a Principal Component Analysis (PCA) in conjunction with a Hierarchical Ascendant Classification (HAC) to compare raw and normalized (i.e. corrected by leg length) data of velocity, step length and frequency. Dimensionless Analysis ensures that differences in sizes of athletes have a minimal influence on gait parameters. Then, the same methodology was applied on velocity and temporal parameters (contact time, flight time, step frequency), and subsequently on velocity and spatial parameters (contact distance i.e. distance travelled during the stance phase, flight distance i.e. distance travelled during the aerial phase, step length) in order to investigate how leg length might affect the spatio-temporal gait parameters. Thereafter, Factorial Discriminant Analysis (FDA) was performed to obtain a predictive model of the classes (skill levels) defined by the HAC.

Results: Our analyses (PCA and HAC) demonstrated that body size did affect gait patterns at maximal sprinting velocity; in particular, the spatial parameters were more affected than the temporal ones by the leg length. Compared with taller athletes, smaller athletes increased their contact distance, probably to compensate for their shorter leg length. However, compared with novices, both advanced sprinters (international and national levels) performed more consistent gait patterns despite leg length differences. FDA showed that the best predictive model was based on four normalized gait parameters: velocity, step length, frequency and flight time. However, further study should be conducted by using such predictive models to validate them.

Conclusions: In conclusion, interpretation of both factorial analyses and classification techniques on raw and normalized data provide valuable information for categorizing athletes according to their morphology and skill level.

WP-23

Effects of cross slope on gait ground reaction forces

D.J. Pearsall, R. Ouckama, J. Loh and C. Bouchard

Kinesiology & Physical Education, McGill University, Montreal, QC, Canada

Introduction: Sidewalks are formed around two slope parameters: grade and cross slope[1,2]. The grade refers to the rise-over-run incline in the direction of travel (typically around a maximum of 8%[3,4]). The degree of slope perpendicular to the direction of travel refers to cross slope, with 2% to 4% maximum[3,4] recommended; however, irregular terrain may push this upward of 9-10%[1]. To date, surprisingly few studies have evaluated cross slope design. Hence, the purpose of this study was

to identify the functional adaptations to maintain forward progression and stability under this terrain impediment.
Methods: Seven male subjects (18 to 25 years) were evaluated. Two different walking conditions were observed: walking on a 0° and 6° cross slope surface. Twenty bare foot walking trials were collected for each condition. Two force plates (AMTI model 0R6-7-1000) were mounted within a platform that could be inclined to the desired cross slope. Several sub-platform braces stabilized the tilted platform-force plate assembly. Parallel strips of tactile tape were placed on top of the force plates to provide sufficient friction to avoid foot slippage. GRF data were collected at 960Hz. Matlab scripts extracted x, y, z force parameters of interest at heel strike (HS), mid-stance (MS), and toe off (TO). An ANOVA was used to compare cross slope conditions (0° versus 6°) for downhill (DH) and uphill (UH) limbs.
Results: Vertical (V) and Antero-Posterior (AP) GRF were similar for both surface conditions; however, substantial Medio-Lateral (ML) GRF differences ($p<0.001$) were observed. The 6° cross slope augmented ML GRF of the DH limb by three fold. Interestingly, while ML GRF for the UH limb also increased, the direction was reversed. Hence, introduction of the modest cross slope required substantial compensatory changes in ML GRF to prevent down slope slippage. With regard to foot placement as measured from center of pressure during stance, step length did not change with cross slope; however, most subjects tended to increase step width (from 4.7 to 7.1 cm).
Conclusions: Increasing step width may be one adaptive control strategy to enhance dynamic stability due to the compromised security of foot placement on cross slopes. From these findings, further study is warranted to identify the effects of varied slopes, surface frictions, and walking speed for different populations. <p>**1.** US Access Board 2002 www.access-board.gov **2.** Kockelman K et al 2001 JRRD 38(1): 101-110 **3.** Infraguide 2004 www.infraguide.gc.ca **4.** US DOT 1999 www.fhwa.dot.gov

WP-24

Head stabilization strategy in presence of floor rotations on horizontal plane

A. Berthoz[1], P. Cappa[2], F. Patanè[2], M. Petrarca[3], S. Rossi[2] and G. Zanelli[2]

[1]LPPA, Collège de France, Paris, France, [2]Mechanical Engineering, University of Rome "La Sapienza", Rome, Italy and [3]Paediatric Neuro-rehabilitation Division, Children's Hospital "Bambino Gesù" IRCCS, Passoscuro (Fiumuicino) Rome, Italy

Introduction: The inertial and gravitational forces are the inputs to the vestibular system of the head and therefore they are relevant variables in the study of the human equilibrium. In the present paper the equilibrium capability of normal subjects was analyzed by studying the cinematic of the head when it is subjected to horizontal rotations. In particular, the head stabilization to rotational movement was investigated in the Transversal plane instead of previous papers (Woollacott 2001, Horak 2003) where the attention was focused mainly on the Sagittal and Frontal Planes.
Methods: The experimental protocol consisted in imposing known horizontal rotations of a moving base to four normal subjects. The chosen angle variation of the moving base, as function of time, was an increasing/decreasing chirp with amplitude equal to +/- 40 deg and a linear frequency range from 0 Hz to 1 Hz and returning to 0 again. The angular acceleration of the head was estimated with an accelerometric array device, capable to measure all the inertial and gravitational inputs on the head. The present device consists in a cyclist helmet equipped with ten biaxial low cost capacitive accelerometers. The sample frequency was 1000 Hz with an accuracy of 1 mg for each sensor and a overall accuracy of 15 deg/s2 for the angular acceleration.
Results: In the trials, we focused the attention on the pattern, as function of time, of the head (a_h) and platform (a_p) angular accelerations evaluated on the Horizontal plane. The results showed an acceleration pattern that can be divided in four phases. The phases corresponds to the following chirp frequency ranges: (p1) 0 Hz to 0.5 Hz, (p2.1) 0.5 Hz to 1 Hz - when the rotational velocity increases - (p2.2) 1 to 0.6 Hz - when the rotational velocity decreases - and (p3) 0.6 Hz to 0 Hz. In the p1 period the maximum value of a_h, in each rotation of moving base, was always greater than a_p and the patterns were in phase. In the p2 period, the maximum value of a_h was lower than a_p but, while during p2.1 the a_h pattern was in moderate phase lag respect to a_p (<45 deg), instead during p2.2 the a_h and a_p were always in 90 deg phase lag. In the p3 period, the maximum value of a_h was again greater than a_p and the patterns were in phase only in the last part of the trial.
Conclusions: In general, the subjects preferred to maintain the head fixed with the trunk when the velocity of the platform was low (i.e. lower than 0.5 Hz); instead, for higher speeds, the subjects tried to reduce the head movement to maintain a safety stability. In conclusion, as the speed increase, the head and then equilibrium stabilization was obtained with a optimal synchronization of the inertial and gravitational inputs on each body part.

WP-25

Functional biomechanics of the abdominal wall - Analytical modeling of stability

M. Gardner-Morse, I.A. Stokes and S.M. Henry

Orthopaedics and Rehabilitation, University of Vermont, Burlington, VT, USA

Introduction: The abdominal wall muscles have numerous poorly understood roles. It is suggested that their activation reduces loading on the spine in extension efforts, and also helps to stiffen and stabilize the trunk. Biomechanical analyses of these muscles is complicated by their being curved, and not attaching from bone to bone, as are most skeletal muscles. The purposes of this study were to (1) construct a biomechanical model of the abdominal wall; (2) integrate it with an existing model of the spine and other trunk muscles (*Stokes IAF and Gardner-Morse M: Lumbar spinal muscle activation synergies predicted by multi-criteria cost function. J. Biomech. 2001; 34(6): 733)*; (3) analyze the interactions between abdominal wall muscle activation and spinal loading and trunk stability.
Methods: The abdominal wall was idealized as a barrel-shaped structure with three layers of muscle having a triangulated mesh with transverse and oblique elements. The three layers represented the transversus, internal oblique and external oblique

muscles. The fascia and the non-contractile direction of muscle were represented by elements having only stiffness. Elements in the contractile direction of each muscle were represented by parallel spring and force-generating elements. Intra-abdominal pressure (IAP) generated forces at the nodes joining the elements. To solve the 'redundancy problem' (more muscles than model degrees of freedom) a cost function having two weighted components (muscle contractile stress squared, and muscle stretch squared) was minimized. Constraints included upper and lower bounds on muscle stress and on intervertebral displacements. The model was used to estimate the muscle tensions and nodal displacements for known levels of IAP and physiological levels of external forces and moments.
Results: For physiological levels of IAP, the percent activation of the abdominal muscles was consistent with those reported from EMG studies. The balance between the axial forces associated with IAP (upwards force on diaphragm – downwards acting force components of tension in abdominal wall) was in favor of the upwards force, implying that abdominal muscle activation and IAP has a net unloading effect on the spine. With plausible values for the stiffness elements in the abdominal wall active and passive components, analytical solutions having only muscle stress squared in the cost function produced solutions with unrealistically large outward bulging of the abdominal wall.
Conclusions: Most statical biomechanical analyses of skeletal muscles acting around joints, including the spine, give physiologically plausible solutions by assuming that muscles are activated to minimize muscle stress (and endurance). The sheets of biplanar curved muscle that form the abdominal wall behave in a more complex fashion, and inclusion of muscle stretch in the optimization cost function was required to produce plausible model solutions.

WP-26

Biomechanical energy harvesting: apparatus and methods

Q. Li[1], J.A. Hoffer[1], A.D. Kuo[2], D. Weber[3] and M. Donelan[1]

[1]School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada, [2]Department of Mechanical Engineering, University of Michigan, Ann Arbor, MI, USA and [3]Department of Physical Medicine & Rehabilitation, University of Pittsburgh, Pittsburgh, PA, USA

Introduction: Biomechanical energy harvesters convert mechanical energy extracted from human movement into electrical energy to power portable devices such as electromechanical and neuroelectric prostheses. Here we describe our novel wearable biomechanical energy harvester (WBEH) technology.
Methods: The device includes subsystems for mechanical power transmission, electrical power generation and control. The transmission system comprises a gear train that transfers the low velocity/ high torque knee joint dynamics into the high velocity/low torque dynamics required for efficient power generation and a roller clutch that only engages the transmission during knee extension. The power generation system comprises a miniature three-phase brushless rotary magnetic generator with a small terminal resistance, to minimize power dissipation, and a low speed constant, to minimize the required gear ratio. The generated power is dissipated by resistors rather than stored in a battery. Given the generator terminal resistance and speed constant, simulations found the unique optimal combination of gear ratio and output resistance to maximize the power output, maximize the mechanical to electrical efficiency and produce a reaction torque equivalent to the joint torque normally produced by muscles during walking at a moderate speed. To evaluate the efficiency of converting mechanical to electrical power, we designed a test bed to drive the WBEH at specified angular velocities using a servo-motor while measuring the reaction torque and the electrical power generation.
Results: In its current configuration, the mechanical to electrical efficiency is approximately 50% with the remaining power being dissipated as heat due to gear friction and electrical resistance within the generator. The purpose of the control system is to selectively engage and disengage power generation to target walking cycle periods when knee muscles normally perform negative work (mutualistic mode). It is currently coded in Simulink and Real Time Workshop with device and computer communication through an umbilical cable. The control system processes knee kinematics from a potentiometer and selectively engages or disengages power generation by completing the circuit between the generator and resistors using a low-latency switch (PhotoMOS relay). A CNC-manufactured aluminum chassis houses the transmission system, the power generation system and the potentiometer. The chassis (0.76 kg) is mounted on a customized commercially-available knee brace (0.89 kg). Human subject testing revealed that the WBEH can achieve, on average, 3 W electrical per device in switch-engaged mode and 2.2 W in mutualistic mode during moderate speed walking (see Naing et al. abstract). For dedicated knee extension, the maximum power output reached 27 W/device.
Conclusions: Our biomechanical energy harvesting technology captures mechanical energy normally wasted during daily activities, providing a promising alternative to batteries for powering portable devices.

WP-27

Validation of length-modulated walking to study the mechanical determinants of metabolic cost in hemiparetic gait

D.N. Hewson[1], A. Christie[1], J.J. Eng[2] and M. Donelan[1]

[1]School of Kinesiology, Simon Fraser University, Burnaby, BC, Canada and [2]School of Rehabilitation Sciences, University of British Columbia, Vancouver, BC, Canada

Introduction: Mechanical work required to redirect the center of mass velocity during step-to-step transitions is a major determinant of the metabolic cost of walking (Donelan et al., 2002). Physics-based models of this transition predict the requisite work is minimized when trailing leg positive work and leading leg negative work are equal, opposite and simultaneous. This optimal transition hypothesis, supported by experiments on healthy subjects, has consequences for hemiparetic gait: if a paretic leg cannot perform the required positive work, mechanical work and metabolic cost would increase. To calculate the contribution of transition work to metabolic cost, experimental designs that isolate it from other metabolic cost contributors are necessary. Donelan et al., (2002) demonstrated that subjects walking faster

by increasing only step length had proportional increases in transition work while limb swing cost remained constant. We propose to use a length-modulated walking protocol to determine if sub-optimal transitions explain the metabolic cost of hemiparetic gait. Our hypothesis is that transition work efficiency during hemiparetic gait is equal to that measured during healthy walking; any increase in metabolic cost is due to an increase in mechanical work. To test this, we must first demonstrate that this protocol is a feasible option for this population.
Methods: We determined each hemiparetic subjects' preferred step frequency and length during overground walking at 0.7m/s, then enforced this frequency by having subjects match the beat of a metronome forcing length to be directly proportional to speed. Step length was enforced with tape placed on the ground. To determine mechanical work using inverse dynamics and the individual limb method, subjects walked across ground-mounted force plates at a range of speeds while wearing active joint markers. To calculate metabolic cost, subjects performed 6 min walk tests under the above conditions. We measured rates of O_2 consumption and CO_2 production using a portable metabolic analysis system.
Results: A wide range of step lengths were achieved (70%-130% of the 0.7m/s length). Step frequency matched the metronome beat for both paretic and non-paretic legs. Percent error across speeds was 1.4±4.3 and 2.0±5.3, respectively. Step lengths were also accurately targeted with -0.5±4.3 and -0.3±3.5 percent error for paretic and non-paretic legs. There was no difference in lengths or frequencies between the paretic and non-paretic legs and there was no systematic relationship between length and frequency.
Conclusions: Length modulation appears to be a feasible protocol for hemiparetic subjects. With our methodology validated, we are now using it to determine the efficiency of performing the work required of step-to-step transitions in hemiparetic gait. This will allow us to quantify the contribution of transition work to metabolic cost, thereby testing whether sub-optimal transitions explain the elevated cost of hemiparetic gait.

WP-28

Inter-segmental motion of the torso during the transition from sitting to standing

M.B. Johnson[1], T.W. Cacciatore[2] and R.E. van Emmerik[1]

[1]Neuroscience & Behavior, University of Massachusetts Amherst, Amherst, MA, USA and [2]Neurological Sciences Institute, Oregon Health & Science University, Portland, OR, USA

Introduction: The head and torso play important roles in posture and movement, yet are rarely a focus of research. Most studies on dynamic movement regard the torso as a rigid segment. Inter-segmental motion of the torso has been identified in gait, but few studies have modeled the torso as more than two segments during other daily activities. The purpose of this study is to develop a multi-segment model of the torso to asses 1) whether torso segments are involved in the sit-to-stand task and 2) if there are differences in the degree of contribution of these segments.
Methods: Fifteen male and 17 female subjects performed five sit-to-stand trials and five 6-second sitting trials. 3-D Kinematic data were collected using motion capture cameras sampled at 100 Hz and filtered at 3Hz. Kinematic data were analyzed for 14 body segments: head, cervical, upper-thoracic, mid-thoracic, lumbar, pelvis, and each thigh, shank, foot and arm. The range of motion (ROM) for joints and segments was calculated and compared between the sit-to-stand and sitting conditions.
Results: A significant difference was found in joint ROM between the sitting and sit-to-stand conditions. There was a significant interaction of joint and movement. After partitioning the data by movement, it was found that there was a significant difference in ROM between joints for the sit-to-stand condition, but not for the sitting condition. The largest ROM was seen in the lumbar/pelvis joint, and the smallest in the upper-thoracic/mid-thoracic and the mid-thoracic/lumbar joints. There was a significant difference in sagittal ROM between torso segments. Of all segments, the head displayed the smallest ROM. The largest ROM was seen in the mid-thoracic and lumbar segments.
Conclusions: Within the torso, large ROM at joints and differences in segment motion indicate that the torso is not moving as a single rigid unit. A common pattern involved the head and pelvis staying somewhat neutral in space, with the lumbar/pelvis joint flexing and other torso joints extending during the course of the movement. However, great between subject variability was observed. A better understanding of inter-segmental torso motion can help identify differences between populations and to identify risk factors for balance or coordination issues and back pain.

Mean range of motion for torso joints during the sit-to-stand and sitting reference conditions and torso segments during the sit-to-stand condition

Joint	Sit-to-Stand	Sitting Reference	Segment	Sit-to-Stand
Head/Cervical	16.6	1.2	Head	17.0
Cervical/Upper-thoracic	16.7	0.9	Cervical	26.6
Upper-thoracic/Mid-thoracic	12.4	1.0	Upper-thoracic	39.3
Mid-thoracic/Lumbar	13.2	0.9	Mid-thoracic	48.6
Lumbar/Pelvis	29.6	0.5	Lumbar	48.1
Hip	89.6	--	Pelvis	44.0

Neurophysiology of Sensorimotor Control 2

WP-29

Navigated transcranial brain stimulation elicited silent period reflects recovery of gait in patients with acute stroke

I.M. Tarkka[1], S. Peurala[3], M. Kononen[2], L. Saisanen[2] and J. Sivenius[1]

[1]Brain Research and Rehab Center Neuron, Kuopio, Finland, [2]Clinical Neurophysiology, Kuopio University Hospital, Kuopio, Finland and [3]Health Sciences, University of Jyvaskyla, Jyvaskyla, Finland

Introduction: In acute cerebrovascular stroke the affected cerebral cortex undergoes structural and functional changes. These may be excitatory or inhibitory. Here we looked electrophysiologically at the inhibitory processes during the early phase of recovery from stroke using transcranial magnetic stimulation. Silent period (SP) is a transient suppression of EMG activity after the motor evoked potential (MEP) when the target muscle is active. Currently very little is known about lower limb SPs and

stroke. The purpose was to demonstrate the behavior of SP in the acute phase of stroke in lower limb muscles and to utilize NBS in accurate localization of subsequent stimuli during the course of early recovery. We hypothesized that the lower limb SPs are related to the early recovery process in acute stroke.
Methods: Patients had on admission first supratentorial stroke (Modified Ranking Scale 0 – 2) and Functional Ambulatory Category (FAC 0 – 3). They had voluntary movement on the leg of the affected side and Barthel Index 25 – 75. Initial diagnosis was made with MRI and 9 patients were followed for 15 days and they all received intensive rehabilitation. Neurophysiological assessment included Navigated brain stimulation (NBS) with resting motor threshold (MT) recorded in TA and SOL muscles bilaterally, MEP above 100μV and silent period (SP) during bilateral voluntary activation at 130 % MT, 5x. SP was defined from the MEP onset to the reappearance of uninterrupted EMG. Navigated brain stimulation, NBS, was performed utilizing IR camera in placing the stimulation coil according to the location information of individual structural MRI (Nexstim Ltd) and surface EMG was recorded (ME6000 biomonitor).
Results: Results of MEP Motor Threshold 130% showed that electric field needed for MT was higher on the affected side than on the non-affected side. MTs were always obtained on the non-affected side. Affected side failed to respond in 3/9 patients in the leg area. MEPs reappeared by 15 days in one patient for leg area stimulation. SPs were obtained in the first acute recording in 5/9 affected legs, after 15 days in 6/9 affected legs. Leg muscle SP durations were significantly longer in the first recording compared to later recordings. The non-affected side SPs were always present. The duration of walking 10 m shortened (5/9) or gait ability reappeared (4/9) during the 15 days that were followed in the functional recovery process. SPs significantly shortened along with the significant speeding up of gait. This indicates reduction in the inhibition of the affected cortical hemisphere.
Conclusions: TMS-elicited silent period most likely reflects cortical inhibition mediated by GABA-A receptors. Prolonged SP in the affected hemisphere suggests increased cortical inhibition. Affected leg muscle SP durations started to shorten, i.e. there was reduction in the inhibition, already during the first week after stroke.

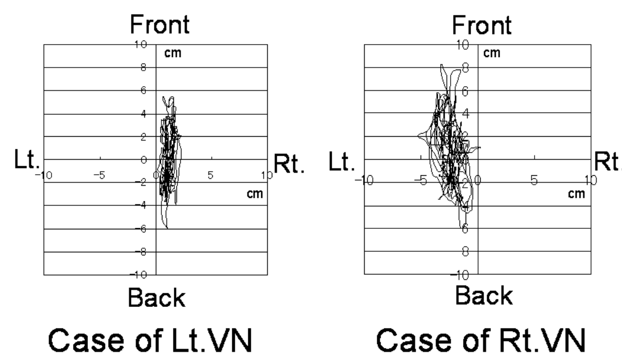
WP-30

Examination of vestibular neuritis patient's Body Tracking Test(BTT)

T. Yoshida, M. Yamamoto, T. Nomura, R. Takazawa, Y. Ikemiyagi and F. Shigeta

Toho university School of medicine, Sakura, Japan

Introduction: The Body Tracking Test (following BTT) is an inspection system for moving the center of gravity in accordance with a move stimulus of a target, and seeing a function of dynamic body balance. We have so far performed various examination about a normal person's tracking. This time, BTT was enforced to the vestibular neuritis patient, and the function of dynamic body balance was examined.
Methods: They are 31 patients which were diagnosed as the vestibular neuritis in the Toho University medical center Sakura hospital otolaryngology, and performed in-patient hospitalization. 15 males, 16 females, and age of the items are 71 years old from 7 years old. The gaze nystagmus was seen and BTT was enforced further in the standing position at the time which can be inspected. 31 people are divided by strength of gaze nystagmus. Grade I were 10 patients,grade II ware 11patients, grade III ware 10patients.. A clear difference was not seen by examination of the lateral difference using the lateral BTT For this reason, the antero-posterior BTT was used for this examination. In the analysis, we used the displacement of center of gravity was seen by using the antero-posterior BTT and the direction body sway average center displacement of X. of antero-posterior BTT.
Results: Carrying out deviation of the vestibular neuritis to an affected side in a static Stabilometry test is known. When X direction shake average center displacement was seen, the position of 0.57cm in right side vesibular neuritis patient of grade III in the left. It was similar, and 0.86cm, and 0.43cm in the left in grade I, the left in grade II.For the left side vesibular neuritis patient, the position of 0.088cm in the right in grade I, 0.33cm in the right in grade II, 0.43cm in the right in grade III was shown.
Conclusions: BTT was enforced to the vestibular neuritis patient, and the function of dynamic body balance was examined. When having the antero-posterior BTT, It has been understood to have the inclination to the normal side and to tracking.



A case of lt. vestibular neuritis: Tracking of deviation to the right is recorded. A case of rt. vestibular neuritis: Tracking of deviation to the left is recorded.

WP-31

Inhibition of anticipatory postural adjustments of trunk muscle responses is associated with the potential to need to stop a sudden movement

G.T. Allison[1] and S.M. Henry[2]

[1]*School of Surgery and Pathology, The University of Western Australia, Perth, WA, Australia and* [2]*Department of Physical Therapy, University of Vermont, Burlington, VT, USA*

Introduction: During rapid arm raising, the deep trunk muscles on the contralateral side of the arm raised are activated prior to the anterior deltoid (AD) muscle, suggesting a role for these muscle in anticipatory postural adjustments (APA). The role of trunk muscles in APAs has been purported to be the orientation and position of the spinal segments and trunk. However, these muscles may also contribute to the body COM control as well as the generation of the arm movement. The deep trunk

muscles are activated independently of the different focal arm perturbations in healthy subjects. In LBP subjects, a motor control deficit has been implicated by this loss of independent control of the deep muscles and the delay in the APA response. However, demonstrating independent control of the APA and focal muscle control systems is difficult. A modified Go-Stop test protocol was used to determine if inhibitory control parameters differentially influenced the deep trunk vs. the focal muscle systems.
Methods: Surface EMG signals were collected (1000 Hz) bilaterally from the anterolateral abdominal (ALA) and AD muscles. Each subject (n=4) was required to rapidly raise her arm to trigger an optical switch. The arm movement was co-ordinated with a rapidly moving clock hand on a computer screen placed in the subject's view. The time difference between the switch and the clock hand reaching the 12 position was used as feedback about accuracy of performance. Two blocks of trials were conducted: first, for training, a set of trials with only GO trials to establish the baseline activation profiles second, a block of GO and STOP trials randomly assigned at a ratio of 5:1 were given. A total of 826 trials were examined with synchronised EMG data amplitude were assessed in an APA epoch -50 ms to +50 ms (0 ms = AD muscle onset); EMG amplitudes were assessed in 4 conditions: Failed stops, 1st and 2nd GO trial after a STOP (T1 & T2) and Partial STOPs.
Results: The Left ALA muscles were active in the APA window prior to AD while the R ALA were activated with AD. The amplitudes of the AD and R ALA muscles were unchanged for failed stop and Go (T1&T2). The RALA was unaffected when the AD was inhibited during partial stops. In contrast, the L ALA demonstrated a constant degree of inhibition for all test conditions (Go or Stop) and is affected by the global potential to STOP (i.e.2nd block).
Conclusions: The APA response of the ALA muscles show laterality differences with the contralateral ALA consistently activated prior to the ipsilateral ALA muscles. Further, the contralateral ALA muscles show an inhibition independent of the trial commands which suggests a central inhibitory effect independent of the trial condition (.ie. the possibility of a stop). The ipsilateral ALA demonstrated little changes under different trial conditions. The asymmetric activation of the ALA muscles has implications in understanding motor control deficits reported in LBP populations and the role these muscles have in APAs.

WP-32

Improvement in stability of the paretic arm in patients with hemiparesis using bimanual arm tasks

K. Ustinova[1] and M. Levin[3]

[1]Department of Physical Therapy, Central Michigan University, Mount Pleasant, MI, USA, [2]Centre for Interdisciplinary Research in Rehabilitation, Jewish Rehabilitation Hospital, Montreal, QC, Canada and [3]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada

Introduction: The paretic arm of individuals with hemiparesis has a diminished ability to resist sudden perturbations and to preserve stable movement patterns compared to healthy subjects. The goal of this study was to investigate how different types of participation of the contralateral arm may influence the stability of reaching movement of the paretic arm in individuals with post-stroke hemiparesis.
Methods: While sitting, non-disabled subjects and patients with hemiparesis on the dominant side performed a task in which they reached forward, grasped and removed a lid from a jar placed in the sagittal midline on a height-adjustable table. The task was performed in three conditions: bilaterally with both arms starting to move simultaneously; unilaterally while the contralateral arm held the jar; and unilaterally with the jar attached to the table. During some reaches, the arm removing the lid was suddenly and transiently stopped by an electromechanical device. Kinematic data from markers placed on the hands, arms and trunk were recorded. Among the kinematics analyzed was the deviation of the reaching trajectory of the perturbed arm in the frontal plane from the trajectory recorded during non-perturbed movement compared to that of the non-perturbed arm and the movement time. Temporal coupling (for bilateral movement only) was defined as a time difference in movement onset and offset between arms.
Results: Results showed that the movement of the paretic arm was more stable when the contralateral arm was involved in holding the jar, compared to the unilateral movement.
Conclusions: The results of this study may be used in the development of new rehabilitation approaches that include bimanual movements to improve functional recovery of the paretic arm in patients with hemiparesis due to stroke. Supported by NSERC.

WP-33

Obstacle avoidance during walking is speeded up with a startling auditory stimulus

A. Queralt[1], V. Weerdesteyn[3], H. van Duijnhoven[3], J. Castellote[5], J. Valls-Solé[6] and J. Duysens[4]

[1]Escola Universitària d'Infermeria, Universitat de València, València, Spain, [2]Facultat de Ciències de l'Actividad Física i l'Esport, Universitat de València, València, Spain, [3]Dept. of Rehabilitation Medicine, Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands, [4]SMK-RDE, Maartenskliniek, Nijmegen, Netherlands, [5]Instituto de Salud Carlos III, Madrid, Spain and [6]Unitat d'EMG, Servei de Neurologia, Hospital Clínic, Universitat de Barcelona, IDIBAPS, Barcelona, Spain

Introduction: Previous studies have reported that startling stimuli can speed up voluntary reactions. Reaction times are shortened by 60 to 120 ms (Carlsen et al., 2004; Valls-Solé et al., 2005) when an acoustic startle is presented simultaneously with the imperative signal to perform, for instance, arm movements to a target. It was suggested that this could be explained by the startle acting as an early trigger for subcortically stored prepared movements. This raises the question whether this phenomenon would also be present for leg movements and for other types of motor responses that are thought to rely on subcortical pathways. One example is the adjustment of stepping trajectories during obstacle avoidance (Weerdesteyn et al., 2004). These reactions are faster than voluntary reactions. Preliminary data indicate that these type of responses are possibly also speeded up by startle (Reynolds and Day, 2005). The aim of the present

study was to examine whether this would also be true for responses to a suddenly appearing obstacle while walking.
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 at one of three phases during the step cycle, namely late stance (LSt), early swing (ESw), and mid swing (MSw). LSt obstacle release was the easiest condition, whereas MSw represented the most difficult condition. To examine the influence of the startle on an obstacle avoidance task, unexpected auditory stimuli were presented simultaneously with the obstacle. Each participant performed sixty obstacle avoidance trials (Obs). In fifteen of these trials, obstacle release was accompanied by the auditory stimulus (ObsStart trials). For both legs, EMG activity was recorded from the biceps femoris (BF), the rectus femoris (RF), the tibialis anterior (TA), and the gastrocnemius medialis (GM).
Results: The most pronounced startle-related differences were found in BF and TA of the ipsilateral leg and in RF of the contralateral leg. The latencies of these three muscles in response to an obstacle were about 20-30 ms shorter in ObsStart trials. In addition, smaller but statistically significant latency differences between Obs and ObsStart trials were found in all the other muscles. Furthermore, onset latencies of both Obs and ObsStart trials decreased when trials became more challenging. MSw yielded the shortest latencies followed by ESw and LSt. The shorter onset latencies in ObsStart trials coincided with higher avoidance success rates. In the Obs trials a total of 18 foot contacts with the obstacle were observed (2.3%), whereas no errors were made in the ObsStart trials.
Conclusions: To conclude, obstacle avoidance under time pressure relies on very fast responses, yet these responses are speeded up with startle, consistent with the notion that these responses consists of triggered responses from subcortical origin. Secondly, there may be a functional advantage of the StartReact phenomenon, as indicated by increased success rate.

WP-34

Parkinson's disease affects perception of surface inclination

P. Carlson-Kuhta[1], F.B. Horak[1], S. Hickey[1] and K. Fujiwara[2]

[1]Neurological Sciences Institute, Oregon Health & Science University, Beaverton, OR, USA and [2]Department of Human Movement and Health, Kanazawa University, Kanazawa, Japan

Introduction: Recent studies have suggested that people with Parkinson's Disease (PD) have impairments in utilizing proprioceptive information. This impairment may be related to balance difficulties seen in PD. The purpose of this study was to determine if PD affects perception of surface inclination during stance.
Methods: We tested 11 PD (53 to 79 yrs) and 11 age- and sex-matched Control subjects (56 to 79 yrs). The PD subjects were tested in the practical OFF state (>10 hrs. off PD medication) and six were also tested in the ON state. Subjects stood blindfolded with each foot on a separate force plate and one plate slowly rotated 4 degrees (reference), after which the second plate rotated 2, 3, 5 or 6 degrees (test) in a toes-up or toes-down direction. Rotation amplitudes and velocities of 0.25, 0.50, or 0.75 deg/s were randomized. The subjects pushed a button when they detected the onset and end of the 2nd plate movement – dynamic surface tilt. After both plates stopped rotating, subjects indicated which ankle was more rotated – static surface tilt. Six PD (ON medication) and six Control subjects were also tested in the same task, but while sitting in a chair. The Motor UPDRS was performed at each test session.
Results: The PD subjects had more errors than control subjects in comparing left and right surface inclinations. During standing trials, control subjects scored better than PD subjects at all test angles. The PD subjects tended to score worse when ON medication compared to OFF medication. For sitting trials, Control subjects also had better scores than PD subjects. Control subjects scored better in standing than sitting for plantarflexion; but not for dorsiflexion rotation. The PD subjects scored better in standing, compared to sitting, for 2 and 3 degrees of rotation and better sitting, compared to standing, for 5 and 6 degrees of rotation for both plantarflexion and dorsiflexion. The difficulty in detecting surface inclination was correlated with severity of PD (UPDRS scores), particularly in the ON medication state, with the most severe PD subjects having the most difficulty in determining the surface inclination. The ability to detect dynamic tilt (pressing button when detected start of platform tilt) was similar between Control and PD subjects.
Conclusions: Subjects with severe, but not mild PD, showed deficits in kinesthetic perception of surface inclination, that may contribute to their postural deficits. The postural kinesthesia was worsened by levodopa medication. The PD subjects' ability to detect surface rotation at the higher angles was better during sitting trials, possibly because they were not simultaneously trying to maintain their balance at the more challenging surface inclination angles.

WP-35

Threshold control of hand configurations

A.P. Sangole[1], A.G. Feldman[2] and M.F. Levin[1]

[1]School of Physical and Occupational Therapy, McGill University, Montreal, QC, Canada and [2]Department of Physiology, University of Montreal, Montreal, QC, Canada

Introduction: A given posture is usually stabilized by forces that resist any deviations from the posture. In order to intentionally move to another posture, the system must reset the stabilizing mechanisms to a new posture. This is achieved by shifting the threshold (referent) configuration of the body or its segments (R configuration) at which muscles begin to be recruited. Then the initial, actual configuration (Q configuration) of the body appears as a deviation from the newly specified R configuration. Because of this deviation, the stabilizing mechanisms provide the muscle activity and forces that tend to diminish the difference by driving the system to an equilibrium posture. The notion of the R configuration applies not only to the whole body but also to single joints or a set of joints. It is hypothesized that the actual and the referent hand-wrist configurations can temporarily match in movements with reversals. Matching will result in minimization of activity of all hand-wrist muscles, regardless of their biomechanical functions, with the depth of the minima constrained by

the degree of co-activation of agonist and antagonist muscle groups.
Methods: Rhythmical hand movement in 3 different postures was recorded using the Optotrack motion analysis system. Subjects sat in a chair with the arm resting on a support and positioned at 45 deg shoulder abduction and 90 deg elbow extension. Six optoelectric markers (120 Hz) were placed on the forearm, radius, metacarpal joint and tip of the thumb and index finger. Muscle activity from 10 muscles was recorded (1500 Hz). Six trials of rhythmical opening and closing hand movements were performed in four hand-wrist initial positions: wrist in flexed position, wrist in neutral position, wrist in extended position, and swinging the forearm while opening and closing the hand.
Results: We identified several hand-wrist configurations at which global EMG minima occurred, thus confirming the notion that movements of the hand-wrist complex results from shifting the threshold configuration.
Conclusions: The findings confirm the notion that multiple muscles of the hand-wrist system can be controlled without redundancy problems by changing the R configuration. Global EMG minima may be a manifestation of a spatial match between the Q and R configurations. Results suggest that a spatial event - matching between the two configurations - might be responsible for a temporal synchronization of activity in neural ensembles.

WP-36

Alteration of muscle tone through conscious intervention: increased adaptability of axial and proximal tone through the Alexander Technique

T.W. Cacciatore, V.S. Gurfinkel, F.B. Horak, P.J. Cordo and K. Ames

NSI, OHSU, Beaverton, OR, USA

Introduction: Muscle tone is fundamental to postural control, however its generation and control are not well understood. Although it provides anti-gravitational support, muscle tone must also sustain a high level of readiness and plasticity necessary to accommodate changing postural conditions. Postural tone plays a central and unique role along the body axis, supporting the spine and mediating intersegmental interactions between limbs. Large (~3-fold), stable differences in axial and proximal muscle tone have been recently reported across individuals, as measured by resistance to slow twisting (Gurfinkel et al., 2006). These differences were related to active adaptation of muscle tone through lengthening and shortening reactions, suggesting differences in an underlying, central state of readiness. Such large differences in tonic adaptability are clinically relevant, however, it is unclear how they can be altered. We examined the effect on muscle tone of the Alexander Technique (AT), a discipline that aims to improve coordination by consciously influencing the state of tone in the neck and back, so that it is elongated and dynamic.
Methods: We compared a population proficient in the AT (AT teachers) with matched controls, and a population of subjects with low back pain before and after AT vs. control intervention. We quantified muscle tone by the maximal resistive torque to slow twisting of axial and proximal segments in standing subjects, evidenced to reflect active muscular forces, and not passive resistance.
Results: Maximal torques for AT teachers were half that of matched controls, differing significantly for the neck ($P<0.001$), trunk ($P<0.001$), and hips ($P=0.016$). Additionally, torque decreased more following AT than control intervention in the trunk ($P<0.05$) and hips ($P<0.05$). The timecourse of resistance also differed; AT teachers had significantly higher phase advance than controls, i.e. reaching neutral (zero-torque) position before re-centering, implying the reduced axial and proximal stiffness with the AT is due, in part, to increased active adaptation. This conclusion is supported by the minimal resistance, and the antiphasic relation between resistance and displacement observed in some AT teachers.
Conclusions: Such adaptability of muscle tone is consistent with lengthening and shortening reactions, observed to relate to the state of central excitability. This suggests the AT influences low-level excitability, presumably decreasing thresholds for tonic modulation. The cognitive nature of the AT's methodology suggests this change may originate from a high level, which is consistent with the reported capacity to cognitively and flexibly influence corticospinal excitability, and thus may represent conscious, high-level regulation over lower levels. Increasing the plasticity of muscle tone by consciously influencing central excitability may constitute a general class of discipline, including the AT and some martial arts, which has potential clinical relevance.

WP-37

The influence of mechanical load on the locomotor pattern in persons with post-stroke hemiparesis

S.A. Kautz[1], C. Patten[3], R.R. Neptune[4], L. Worthen[3] and C.M. Kim[3]

[1]VA Brain Rehabilitation Research Center, Malcom Randall VA Medical Center, Gainesville, FL, USA, [2]Physical Therapy, University of Florida, Gainesville, FL, USA, [3]Rehabilitation R&D Center, VA Palo Alto Health Care System, Palo Alto, CA, USA and [4]Mechanical Engineering, The University of Texas, Austin, TX, USA

Introduction: Persons with post-stroke hemiparesis typically exhibit a profoundly asymmetric gait, in which neither leg generates its usual motor pattern. Rather than abnormal bilateral coordination, this asymmetry is often treated clinically as a unilateral control deficit in the paretic leg accompanied by functional compensation to altered task mechanics in the non-paretic leg. This study used a pedaling paradigm to elucidate the role of mechanical load in the generation of the bilateral hemiparetic motor pattern. We tested whether 1) the paretic (and non-paretic) leg used the same motor pattern as a non-disabled leg when pedaling against the same mechanical load, and 2) the motor pattern is affected by changes in mechanical load.
Methods: Forty-nine subjects with chronic post-stroke hemiparesis and twenty non-disabled control subjects pedaled against various decoupled mechanical loads (i.e., independent pedaling cranks were servomotor driven to emulate the work output from the contralateral leg; Kautz et al., 2006) while we recorded EMG and pedal forces. Controls pedaled with their right leg against loads experienced by normal, paretic and non-paretic legs. Hemiparetic subjects pedaled with their paretic leg against loads experienced by a normal or paretic leg and with their non-paretic leg against loads experienced by a normal or non-paretic leg.

Results: Surprisingly, when non-disabled control subjects pedaled against the simulated paretic workload vastus medialis (VM) activity was produced in the upstroke. However, this VM activity differed from the prolonged activity that characterizes paretic limb coordination deficits. Control subjects pedaling against the simulated non-paretic workload produced significantly less negative mechanical work during the upstroke, with similar coordination as the non-paretic leg in hemiparetic subjects. Nine of sixteen subjects with severe hemiparesis were able to pedal against a generic normal workload with their paretic leg. Even though work output was dramatically increased (~ 2 to 25 J), impaired EMG activity in these subjects was little changed. While prolonged VM activity was somewhat decreased, it was still substantial. Subjects with mild and moderate hemiparesis used the same non-paretic motor pattern whether the non-paretic leg pedaled against a generic normal workload or against its typical non-paretic workload (e.g., they provided more net assistance during the upstroke even though it was not mechanically necessary).
Conclusions: In general, the analyses showed: 1) the paretic leg does not (while the non-paretic leg does) use the same motor pattern as a non-disabled leg to pedal against the same mechanical load; and 2) the paretic and non-paretic motor patterns do not depend on the mechanical load. Of particular interest is that the compensatory non-paretic pattern is preferentially used in situations where it is mechanically feasible, although it is not necessary. **Acknowledgements:** Funding was provided by NIH grant R01 HD37996.

WP-38

Assessing the contributions of optic flow: Strategies to improve gait in Parkinson's disease

Q.J. Almeida[1] and K. Ersser[2]

[1]Movement Disorders Research Centre, Wilfrid Laurier University, Waterloo, ON, Canada and [2]Biology, Wilfrid Laurier University, Waterloo, ON, Canada

Introduction: Visual cues are an effective strategy for improving gait in individuals with Parkinson's disease (PD), yet we do not fully understand the neural mechanisms that allow such improvements. Research tends to support the notion that optic flow may contribute to increased stride length and hence velocity in PD. For example, Azulay et al. (1999) utilized lines that were stroboscopically projected to suppress dynamic vision, and demonstrated that the typical gait improvements expected in PD were not observed. It is important to consider whether vision may compensate for other primary sensory deficits in PD. The goal of the current study was to assess how visual optic flow cues influence gait, when separated from other potential sources of feedback. Isolation of visual feedback was achieved by moving optic flow from the feet to the eyes.
Methods: 20 PD "Off" anti-Parkinsonian medications (average=14.7hrs), and 11 healthy age-matched control participants were tested. Participants walked across a computerized carpet in four visual conditions: i) Normal Vision: walking at self-selected pace with normal vision available, ii) Ground lines: walking while stepping toward lines, iii) Optic flow cues: walking at a self-selected pace while wearing a visual feedback device (providing the illusion of moving lines for feet to step towards), and iv) Optic flow plus: attending to an auditory metronome that matched the self-selected pace of the participant (as determined in condition i).
Results: Optic flow did not elicit improvements in step length or velocity for the PD participants; only the ground lines improved step length. Therefore, optic flow alone could not improve normal step lengths in individuals with PD. Only when vision was available did normal stepping occur.
Conclusions: Our results suggest that conscious perception of motion, produced in part by vision and proprioception is required for improvements in locomotion.

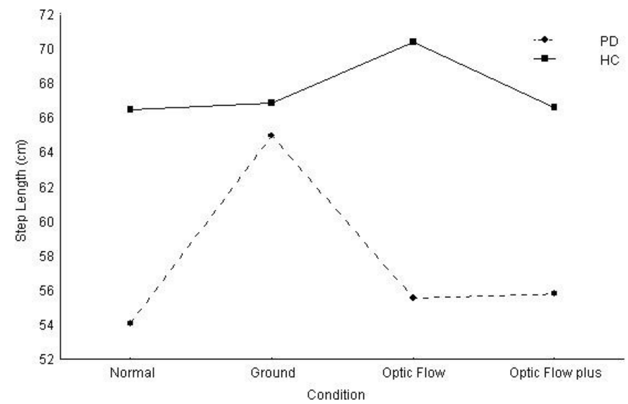


Figure 1. Step length of individuals with PD and healthy participants in the visual cueing conditions

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WP-39

During walking with crutches, self-induced arm unloading responses are smaller than externally triggered ones

J. Duysens[1], B. Baken[1], C. Hauser[2], B. Smits-Engelsman[5] and V. Dietz[3]

[1]Radboud University, Nijmegen, Netherlands, [2]ETH Zurich, Zurich, Switzerland, [3]University Hospital Balgrist, Zurich, Switzerland, [4]Sint Maartenskliniek, Nijmegen, Netherlands and [5]K.U. Leuven, Leuven, Belgium

Introduction: Anticipation can change the amplitude of reflexes during gait. For example, the size of cutaneous reflex responses, elicited by electrical stimulation during gait, can be decreased by as much as 30% when subjects are allowed to trigger the stimulus themselves (Baken et al., 2006). To investigate whether the same is true for responses induced by mechanical stimuli, a group of young adults walked with 2 crutches on a treadmill. One of these crutches could collapse just after touchdown, either on command of the subjects themselves or when triggered externally. This perturbation has the advantage that it produces a series of compensatory EMG responses with different latencies, allowing to study whether anticipation acts primarily on short or long-latency EMG respons
Methods: A custom-made crutch was designed which can be suddenly shortened after a trigger pulse from a computer. A sensor embedded in the shortening-construction of the crutch recorded whether the crutch was in the shortened or in the normal state. A second sensor was placed at the distal end of the crutch to register the onset and termination of the stance phase. Subjects were asked to walk on a treadmill and perform a swing-through crutch-walking task in which both feet performed a

swing simultaneously while both crutches were in the stance phase. EMG activity of eight arm muscles was recorded, i.e. ipsi- and contralateral biceps brachii, triceps brachii, deltoideus anterior and posterior.
Results: The unloading started 44 and 49 ms after first crutch ground contact for the externally and the self-triggered shortening, respectively. Full unloading was reached 103 and 106 ms after first crutch contact for these 2 conditions. Three muscle responses (EMG) were detected (R1, R2 and R3) occurring respectively at latencies of 0, 70 and 145 ms after full unloading. It was found that all eight arm muscles showed a pattern of amplitude reduction in the subject-evoked responses as compared to the computer triggered ones. The reduction in EMG amplitude was usually largest in the first response following collapse and the difference subsided in later responses (36, 22 and 17% reduction for R1, R2, and R3, respectively). In contrast, no reduction was found in the background EMG activity preceding the onset of the self-induced perturbation. The earliest response showed strong habituation in the externally-triggered but not in the self-induced trials in ipsilateral biceps braccii.
Conclusions: It was concluded that sudden unloading during crutch-walking yields a series of responses presumably aimed at maintaining balance. It is argued that the earliest responses (R1) due to unloading of the crutch are startle-related since these responses are reduced most strongly by anticipation. Later responses may be related to muscle stretch or vestibular input and these responses are less susceptible to habituation although more time is available for interaction in the pathways concerned.

WP-40

Stroke patients with spatial neglect display a considerable slowness in the execution of their postural adjustments

D. Pérennou and B. Amblard

service de rééducation neurologique - CHU, Dijon, France

Introduction: Clinical studies have repeatedly shown a better balance recovery in left brain-damaged patients (LBD) than in right brain-damaged patients (RBD), indicating a propensity of the right hemisphere (RH) for postural control. Could this predominance be partially supported by a control of the postural coordination strategies?
Methods: Methods: We investigated the multisegmental stabilization strategies in 27 sub-acute stroke patients and eight healthy controls attempting to maintain their lateral balance while sitting on a freely rocking support. In this task, subjects are responsible both for their imbalance and active correction. Fifteen patients with a right stroke (RBD, including seven neglect patients) were age- and lesion-matched to 12 patients with a left stroke (LBD). The kinematics of body movements in the roll plane was analyzed by means of an automatic optical TV image processor (VICON). Postural stability was quantified by the amount of sway at the level of the pelvis. Multisegmental stabilization strategies were quantified by means of anchoring indices and cross-correlation functions.
Results: Results: RBD were more unstable than LBD and this instability was related to spatial neglect. Unlike normals and LBD, RBD were unable to stabilize their shoulders in space, and to dissociate the upper and lower parts of the trunk. This global trunk stiffness was related to the position sense impairment, and was detrimental to body stability. Patients with spatial neglect displayed a considerable slowness in the execution of bottom-up postural adjustments (postural bradykinesia), which crucially altered their stability. This might be due to non-operational feedback, to a trouble in movement planification, or to an altered motor execution.
Conclusions: This finding may explain why stroke patients with spatial neglect show longer and worst postural recovery than other patients.

WP-41

Corticospinal drive contributes to arm muscle activity during human walking

D. Barthélemy, M. Korchi and J. Nielsen

Medical physiology, University of Copenhagen, Copenhagen N, Denmark

Introduction: Locomotion is generated by a combination of descending supraspinal drive, rhythmic spinal networks and sensory feedback mechanisms. In the cat, the corticospinal tract mainly contributes to the control of fore- and hindlimbs in relation to modifications of gait and during skilled locomotion requiring precise placement of the paws (Drew et al. Brain Res Rev. 2002; 40:178-91; Bretzner and Drew J Neurophysiol. 2005; 94:673-87). Evidence suggests that the corticospinal tract may play a more significant role in the control of uncomplicated human walking (Petersen et al. J Physiol. 2001; 537:651-6). Indeed, weak transcranial magnetic stimulation (TMS), which inhibits the activity of corticospinal tract cells, produces a significant depression of the ongoing EMG activity in leg muscles during treadmill walking. This suggests that the corticospinal tract makes a direct contribution to the muscle activity in the legs even during uncomplicated treadmill walking. Whether this is also the case for the rhythmic activity in the arm muscles, which is seen during human walking, is not known. It was suggested in a recent study that spinal networks in the brachial enlargements may be responsible for this muscle activity as a remnant of quadrupedal locomotion (Dietz et al. Eur. J. Neurosci. 2001; 14:1906-14). Thus in the present study, we used the same technique as Petersen et al. (2001) to investigate whether the corticospinal tract may also contribute to some of this arm muscle activity.
Methods: 17 healthy subjects walked on a treadmill at a comfortable speed (3.5 to 4 km/h). TMS was applied through a figure-of-eight coil at low intensity (at or below threshold for a motor evoked potential; MEP), over the arm area of the left motor cortex. EMG was recorded from the contralateral deltoid posterior, deltoid anterior, biceps, triceps, flexor carpi radialis and extensor carpi radialis.
Results: In 14 of the subjects, TMS induced a suppression of the EMG activity in one or more muscles, at latency 5-10 ms longer than the onset of the MEP. The suppression was most commonly observed in the deltoid posterior and triceps muscles, which were also the most active muscles during walking. The suppression could be observed without any prior facilitation of the EMG activity, suggesting that it was not caused by

activation of inhibitory mechanisms distal to the motor cortex, but rather, as suggested also in previous studies (Davey et al. J. Physiol. 1994; 477: 223-35; Petersen et al. 2001), by activation of cortical inhibitory interneurones.
Conclusions: The observation of the EMG suppression in arm muscles during walking suggests that the muscle activity is at least partly generated by corticospinal drive to the spinal motoneurones. *Supported by CIHR, Danish Society for Multiple Sclerosis and the Elsass foundation.*

Techniques and Methods of Posture and Gait Analysis 2

WP-42

Can variability of spatial and temporal gait characteristics be measured reliably?

J.S. Brach[1], S. Perera[2], S. Studenski[2] and A. Newman[3]

[1]*Physical Therapy, University of Pittsburgh, Pittsburgh, PA, USA,* [2]*Geriatric Medicine, University of Pittsburgh, Pittsburgh, PA, USA and* [3]*Epidemiology, University of Pittsburgh, Pittsburgh, PA, USA*

Introduction: Gait variability is emerging as an important indicator of mobility in older adults; however, its measurement characteristics are largely unknown. To examine the test-retest reliability and concurrent validity of variability of spatial and temporal gait characteristics.
Methods: Participants included 558 older adults from the Cardiovascular Health Study (mean age 79.4 years, mean gait speed 1.00 m/s, 61% female, 23% black) and 20 older adults from the gait adaptability study (mean age 74.3 years, mean gait speed 1.07 m/s, 60% female, 10% black). Gait characteristics were measured using a 4-meter computerized walkway (GaitMat II, E.Q. Inc, Chalfont, PA). Standard deviations (SD) determined from the steps recorded were used as the measures of variability. Intraclass correlation coefficients (ICC) were calculated to examine the immediate and one week test-retest reliability of 4 and 8 meter walks.
Results: One-week test-retest reliability for the 8-meter walk were quite similar to the immediate test-retest reliability, with ICCs ranging from poor for step width variability (ICC=0.37) to fair to good for stance time and step length variability (ICC= 0.53 and 0.58, respectively). Gait variability measures from the 8-meter walk demonstrated greater immediate test-retest reliability than those from the 4-meter walk. Increased step length and stance time variability were associated with poorer levels of health, functional status, and physical activity, where as increased step width variability was associated with individuals reporting difficulty with IADL or walking a half mile.
Conclusions: Gait variability calculated from a limited number of steps has fair to good test-retest reliability and concurrent validity for health, functional status, and physical activity. Gait variability calculated from a greater number of steps should be assessed to determine if the reliability of the measure can be improved.

WP-43

Reproducibility of variability

R. Moe-Nilssen[1], M.K. Aaslund[1] and J.L. Helbostad[2]

[1]*Dept. of Public Health and Primary Health Care, University of Bergen, Bergen, Norway and* [2]*Dept. of Neuroscience, Norwegian University of Science and Technology, Trondheim, Norway*

Introduction: Variability in motor control has intrigued researchers for many years. Gait lends itself to the study of variability, because gait is a cyclic movement, and also involves balance control. Thus both regularity and variability are issues of interest. However, if reproducibility is low, any variable will show high variability, and random error may be misinterpreted as a marker of motor control. Surprisingly, reports on reproducibility are scarce for variability measures. In this presentation, we will report on the reproducibility of selected gait variability and regularity measures, then we will demonstrate how interpretation may be obscured when reproducibility is low.
Methods: Twenty-six elderly subjects walked back and forth a GAITRite walkway at preferred speed. Mean values from the two walks were used in the analysis. After a short interval, the procedure was repeated. Data on step width, stride time and stride velocity were chosen to demonstrate footfall variability, and intrasubject standard deviation (SD) and coefficient of variation (CV) calculated as measures of variability. A trixial accelerometer over the lower trunk was used to obtain autocorrelation coefficients as measures of trunk acceleration regularity along 3 cardinal axes.
Results: Test retest reliability for step width variability, stride time variability and stride velocity variability was low when assessed by ICC(1,1) for SD (0.24, 0.31, 0.06 respectively), and also for CV (0.11, 0.23, 0.15 respectively). Reliability for trunk acceleration regularity was higher, ranging from 0.55 to 0.76 for interstride regularity and from 0.82 to 0.91 for interstep regularity.
Conclusions: Spearman's Rho for intrasubject SD versus intrasubject mean indicated SD was unrelated to the magnitude of the mean for the footfall variables. Hence CV may not be an appropriate measure of variability for these variables [1]. Further, if CV is calculated as SD/mean when reliability of SD is low, the nominator would not discriminate between subjects, while the denominator would return a CV which is inversely proportional to the magnitude of the mean. This may lead to the spurious conclusion that subjects having the smallest mean value also have the highest variability. Unless proportionality is established for intrasubject SD versus intrasubject mean, and reliability of intrasubject SD is adequate, reports based upon CV as a measure of variability should be interpreted with caution. The high reliability shown for the trunk acceleration regularity measures in this study strengthen conclusions from previous research where these measures showed good discriminatory ability [2].
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WP-44

Differences between older and younger subjects in response to variation of the gain of visual feedback of sway

M. Hawken[1] and C. Kennard[2]

[1]Sport & Exercise Sciences, Liverpool John Moores University, Liverpool, UK and [2]Clinical Neuroscience, Imperial College London, London, UK

Introduction: Visual display of subjects' sway is a common method of balance training and assessment in older subjects. Sway feedback increases the accuracy and timeliness of information about sway, feedback gain will obviously affect this. Apart from recent studies by Rougier et al. (e.g. 2004) using centre of pressure feedback the effect of changing gain has been little studied. This study therefore examined performance in subjects of different ages over a range of feedback gains.

Methods: Gain was specified in degrees of visual angle moved by the feedback indicator per degree of anterior-posterior sway. The following seven conditions were tested: Eyes Closed, Eyes Open (fixed indicator), and feedback gains of 0.2, 0.5, 1.0, 2.0 and 5.0. Order of presentation was counterbalanced, requiring 35 male (20-79 yrs) and 35 female subjects (21-83 yrs), 7 in each of the five age groups studied: 20-25, 26-45, 46-65, 66-75, 75+. Clinical examination excluded subjects with conditions affecting postural control. Subjects stood on a fixed surface, viewing a display mounted at eye level 1.0m away. A-P motion at sacral level generated an electrical signal representing sway angle which was scaled and fed to the feedback display, and the RMS amplitude of sway in degrees over 60 seconds was calculated. Analysis was by repeated measures ANOVA with between subjects factors SEX and AGE_GROUP and within subjects factor GAIN, significance level set at $p<0.05$. The RMS sway values were skewed and so were normalised by natural log transformation.

Results: Subjects in general reduced sway below the Eyes Open level using feedback; none were destabilised. There was a significant interaction between AGE_GROUP and GAIN ($F[24,360] = 2.040$, $p = 0.013$) and the main effects of GAIN ($F[24,360] = 87.271$, $p < 0.001$) and AGE_GROUP ($F[4,60] = 14.624$, $p < 0.001$) were significant. No other effects or interactions were significant. The sway of the two younger groups was in most cases lower than that of the three older groups in the feedback conditions and tended to reduce as feedback gain increased, while sway in the three older groups varied less as gain increased. A high-pass filtered (3 pole Bessel, -3dB 0.09Hz) version of the data showed little change in RMS sway amplitude over the different gains after filtering, although the younger groups again had lower sway.

Conclusions: Subjects were able to reduce their sway as gain increased, but older subjects were in general less able to benefit indicating that factors other than quality of information limited their performance. Feedback was effective mainly at lower frequencies, consistent with a finding in Rougier et al. (2004). Older subjects' inability to reduce sway further at the higher gains suggests that choice of gain may influence the effectiveness of training and assessment protocols which use sway feedback. Rougier P, Farenc I, Berger L (2004) Modifying the gain of the visual feedback affects undisturbed upright stance control. Clin. Biomech. 19(8) 858-867.

WP-45

The reliability of timing walks, turns and steps during the 6 minute walk test

J. Wall, C.P. Gray and B. Dale

Physical Therapy, University of South Alabama, Mobile, AL, USA

Introduction: The six-minute walk test (6MWT) measures the distance that a person can walk in 6 minutes. This figure provides no information about performance quality during the test and so a test has been devised which allows for the timing of walks, turns, and steps throughout the test.

Methods: A walkway 12m in length was used for the test. The central 6 meters were used for measuring the walks and the three meters at either end for timing the turns, one of which is to the subject's right and the other to the left. Optical switches emitted a beep when the subject entered and left the central region of the walkway. Five subjects with varying levels of functional mobility were videotaped as they completed the 6MWT. Two raters independently analyzed each of the videotaped walks with multimemory stopwatches. Due to the limited storage capacity of the stopwatches the tapes had to be viewed twice. During the first viewing the walks and turns were timed and during the second viewing left and right step times were measured. A computer program was written that allowed all the timing to be done during one viewing of the tape. The same two raters also analyzed the videotapes using this program. Times were obtained for 181 walks, 177 turns and 181 left and right steps. Rater performances were compared using the stopwatches versus the computer program. The data were analyzed using intraclass correlation coefficients (ICC 2,1).

Results: The results are shown in Table 1.

Conclusions: The results indicate that there is a very high correlation between raters for the walk and turn measurements using both stopwatch and computer techniques but slightly less so for the measurements of step times. When comparing the results obtained by the two timing techniques each rater demonstrated very high correlations for the walk and turn data with high correlations for the steps data. Timing each walk and turn provides information on how a subject performs throughout the 6 minutes. Conditions, such as fatigue or pain, may compromise performance and result in a decreasing walking speed throughout the test. The added information provided by this test may be useful clinically both for making treatment decisions and as outcome measures. However, it is important to point out that these results were obtained from analysis of videotape and further study is needed to determine if measurements made in real time are as reliable.

Table 1. The correlation coefficients (ICC 2,1) obtained for inter-rater comparisons for the stopwatch and computer techniques as well as the comparisons between the two techniques by each of the two raters.

Measurement	Rater 1 vs Rater 2 Stopwatch	Rater 1 vs Rater 2 Computer	Stopwatch vs Computer Rater 1	Stopwatch vs Computer Rater 2
Walk	.998	.995	.998	.995
Turn	1.000	.999	1.000	.999
Left Step	.838	.827	.839	.804
Right Step	.846	.827	.858	.787

WP-47

Detection of regularity sway of the gravic body sway at the time of postural control. -Comparison of the example of Normality, vestibular neuronitis, bilateral canal paralysis and spino cerebellar degeneration(SCD) –

M. Yamamoto, T. Yoshida, T. Nomura, R. Takazawa, Y. Ikemiyagi and F. Shigeta

otorhinolaryngology, Toho university school of medecine, Sakura, Japan

Introduction: The body sway of human standing postural control 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. There are various indices in the method of checking regularity. By employing efficiently the feature which the index has, it compared about the feature of the sway when being accompanied by an obstacle with existence of the frequency where normal sway was stabilized by the FFT power-spectrum analyzing method for expressing the feature of sway of each. The possibility about the diagnosis of a disease can be explored according to the feature of this sway.
Methods: The example of vestibular neuronitis used the subject data of 34 examples, 36 examples of a bilateral canal paralysis, and 35 examples of SCD on the basis of 153 normal subjects. Analysis frequency divided the frequency up to 0.02 to 10Hz into 512 bands, and analyzed the power of the frequency of each of 512 bands. The coefficient of variation compared variation for the power of each frequency band. The method of analyzing for comparing variation mainly used the coefficient of variation.
Results: The normal person's coefficient of variation took out seven or less-coefficient of variation small frequency. In the vestibular neuronitis, eyes open of lateral sway showed the frequency where the eyes closed was also stabilized in high frequency to high frequency. The frequency stabilized in eyes open of antero-posterior sway was a result which is few and has few frequency bands stabilized also in the eyes closed. The example of the bilateral canal paralysis showed the frequency band with little variation in 5Hz - 7Hz of frequency about lateral sway and antero-posterior sway. However, two to 5 Hz showed the frequency band with large variation. Having the sway stabilized in comparatively high frequency heard . SCD showed frequency with little variation to the high frequency region. It has a frequency band common to each, and the band which is common in it being normal is concentrated on low frequency.
Conclusions: In order to find a normal person, the constancy of sway for every disease, and the feature, search about existence of a band with little variation has been performed. As a result, it turned out that it has a frequency band with little variation in each disease also according to the obstacle. If the frequency except having frequency common about the case which the analysis about various cases and comparison are required, and performed about these frequency bands being peculiar to a disease this time from now on shows the feature of an obstacle By a body balance function, the differential diagnosis of a part of lesion becomes possible, and clinical application is attained.

WP-48

Falls in Parkinson's disease: an unstable sitting paradigm to study postural control of the trunk

E. van Wegen[1], M. Rietberg[1], P. van der Burg[2], J. van Dieen[2] and G. Kwakkel[1]

[1]Rehabilitation Medicine, Physical Therapy, VU University Medical Center, Amsterdam, NH, Netherlands and [2]Institute for Fundamental and Clinical Human Movement Sciences, VU University, Amsterdam, NH, Netherlands

Introduction: Postural instability and falls are a major mobility problem in Parkinson's disease (PD) and have a large impact on Quality of Life. Since evidence suggests that dynamic trunk control is changed in PD patients (1), it was decided to study dynamic trunk control in isolation from lower extremity influences in PD patients with and without recent falls.
Methods: Eight PD-fallers, 8 non-fallers and 8 healthy controls participated in an unstable sitting paradigm used to study trunk control. Balance performance was quantified using standard measures of Center of pressure (CoP) excursions (measured with a custom force platform) and trunk angular deviations (measured with a goniometer). In addition, the percentage of trials in which the subjects had to grab the rail for assistance and the associated endurance time were determined. Subjects performed 5 trials (max. duration 15 seconds).
Results: The percentage of successful trials was significantly lower and the endurance time was significantly shorter in the PD patients (p-values < 0.01). The PD non-fallers had a significantly higher percentage of successful trials than the PD-fallers ($p=0.02$). The CoP excursion was significantly different between all three groups ($p=0.012$). The medio-lateral CoP excursion was significantly smaller in non-fallers and controls than in fallers ($p=0.011$). In addition, maximal medio-lateral CoP excursion, Sway area and Sway path showed trends towards significance (resp. $p=0.085$, $p=0.070$ and $p=0.069$). In a multivariate analysis, the angular deviations of the trunk were significantly smaller in the Parkinson patients compared to controls ($p<0.001$). Specifically, angular deviations in the sagittal plane were significantly larger in the healthy group compared to the PD patients ($p<0.001$).
Conclusions: As hypothesized, PD patients showed changes in dynamic balance control of unstable sitting. The groups could be discriminated not only in endurance time and number of successful trials, but also in the amplitude of CoP excursions and angular deviations.The larger medio-lateral CoP excursions in conjunction with increased anterior-posterior trunk angular deviations may point to specific problems with lateral balance control. Our results extend earlier findings (1) in showing that also during unstable sitting, in which influence of lower extremity movement has been eliminated, PD patients show alterations in dynamic lateral balance control of the trunk. Changes in trunk control may therefore be related to the high prevalence of postural instability and falls in PD. Whether this is primarily caused by altered control strategies such as increased co-contraction or trunk rigidity needs further study. Reference 1. Adkin,A.L., Bloem,B.R., and Allum,J.H. (2005): Trunk sway measurements during stance and gait tasks in Parkinson's disease. Gait Posture., 22:240-249.

WP-49

Long-term monitoring of gait in Parkinson's Disease

S. Moore[1], H. MacDougall[1], J. Gracies[1] and W. Ondo[2]

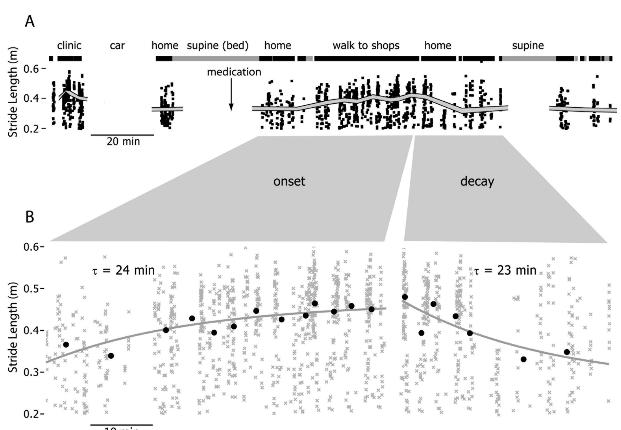
[1]Neurology, Mount Sinai School of Medicine, New York, NY, USA and [2]Neurology, Baylor College of Medicine, Houston, TX, USA

Introduction: One of the primary clinical manifestations of Parkinson's disease (PD) is locomotor dysfunction. While initially manageable with levodopa, involuntary movements and abrupt and unpredictable responses to medication in advanced stages complicate dosing. Typically, clinical evaluation of gait in PD consists of observation of the patient during standardized motor tasks that only provide a snapshot of locomotor performance.

Methods: We have developed a system for measuring the characteristics of every stride taken by a subject over extended periods (10 hours) using a lightweight (<100 grams) ankle-mounted sensor array that transmits data wirelessly to a small pocket PC at a rate of 100 Hz. Stride length is calculated from the vertical linear acceleration and pitch angular velocity of the leg with an accuracy of 5 cm.

Results: Results from PD patients (15) demonstrate the effectiveness of long-term monitoring of gait in a natural environment. Many of the fluctuations of efficacy associated with levodopa therapy, such as delayed onset, wearing off, and the 'off/on' effect, could be reliably detected from long-term changes in stride length.

Conclusions: Clinicians typically see a 'snapshot' of the patient's motor state and management of PD often involves a trial and error approach, relying heavily on the patient's subjective feedback to optimize the levodopa dosage regime. Objective long-term data obtained from stride monitoring may provide a faster and more valid end-point.



The effect of levodopa administration on stride length during natural daily activities outside of the clinic in a patient with advanced PD. (A) Three hours of activity; thick black lines above the stride data indicate locomotion; thick grey lines show periods where the participant was supine. (B) An exponential fit to binned mean stride length was used to estimate the time constant of onset (24 min) and decay (23 min) of levodopa.

WP-50

Quantification of Dynamic Postural Stability in Young Subjects

S.N. Fu and W.W. Tsang

Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China

Introduction: Postural instability is a common concern in subjects with torn anterior cruciate ligament. However, most of the tests for balance control are designed mainly for the elderly. There is a need to develop a test to quantify balance control for young individuals.

Methods: This was a cross-sectional study on 10 healthy and 10 subjects with chronic joint instability associated with torn anterior cruciate ligament(n=5 with injury in the dominant and non-dominant knee). Subjects were aged between 17 and 30. A stepping-down paradigm was designed to capture postural stability during landing with different turning angles. This task was simulate to the most common conditions, i.e. stair descending and turning, that they perceived instability during their daily activities. Both healthy and injured participants were requested to step down from a stool of 20 cm high, from 3 positions (0,30 and 60 degree to a force-plate) and to maintain their balance single-legged when landed. The maximum body sways and time to stabilization along antero-posterior (A-P) and medial-lateral (M-L) directions were measured. Each subject had to perform 10 steps from each position.

Results: In the healthy group, the maximum sways along the A-P direction were greater when landed from either 30 or 60 degree than 0 degree($p>0.05$).In the male healthy subjects the dominant leg had less maximum sway along both A-P and M-L directions when stepping down from 30 and 60 degree($p < 0.05$). In the injured subjects, the maximum sways along the A-P direction was found significantly increased when landed on the injured leg at 60 degree (Fig. 1a, $p<0.05$); the time to stabilization along the A-P direction also increased significantly when landed at an angle of 30 and 60 degree(Fig. 1b, $p< 0.05$).

Conclusions: Using a stepping-down paradigm, greater challenge on postural control is observed when young subjects landed at angled positions. In addition, greater postural sways and time to stabilization are found only when injured subjects landed at 30 and 60 degree. Such findings show that stepping-down paradigm at an angle can be used to quantify postural control in young subjects with postural instability associated with anterior cruciate ligament injury.

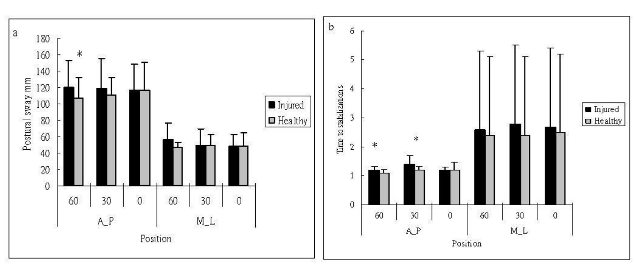


Fig. 1 Postural sway and time-to-stabilization when injured subjects landed from a stepping-down task. A_P, M_L denote antero-posterior and medial-lateral respectively. * indicates significant difference at P<0.05

WP-51

Design and validation of low cost wireless system to evaluate gait variability

H. Tanwar[1], L.M. Decker[2], J.M. Huisinga[2] and N. Stergiou[2]

[1]Computer and Electronics Engineering, University of Nebraska Lincoln, Lincoln, NE, USA and [2]Health Physical Education and Recreation, University of Nebraska Omaha, Omaha, NE, USA

Introduction: Gait variability, as it can be measured from parameters such as stance and step times, can assist in better understanding motor disabilities. In our laboratory we have developed the wireless Gait-O-GramTM (GOG) for this purpose. Similar to a Holter device (a portable electrocardiogram), the GOG can be used by an orthopedist to evaluate gait variability. Instead of analyzing the average of few steps, gait fluctuations over time are examined giving detailed information about the temporal variables during continuous walking. The purpose of this study is to present the design and the validation of our device.
Methods: The wireless GOG system consists of two force sensitive sensors that are placed on a subject-specific cut polyurethane insole at the first metatarsal and heel of the right foot to determine heel strike (HS) and toe off (TO). The system is designed for minimal weight and maximal compactness to reduce hindrance to normal gait pattern. The wireless connection is made through a Bluetooth transmitter (Tx) and receiver, the BlueSentry (BS) from Roving Networks. The whole modular circuit (amplifier and Tx) is contained in a light weight box, and is strapped on to the lateral side of the subject's lower leg. As the subject walks, the signals from the sensors are collected at 400Hz and transmitted by BS to the base station at 230 kbps. The software collects the data, filters noise and outputs time series for further analysis. LabVIEW 8.0 is used as the graphical development environment. Detailed sensor data analysis, filtering, gait pattern recognition and stance phase (SP) calculation are done in a separate module. We validated the ability of the device to detect the SP duration by comparing overground results from the GOG with those from a Kistler force platform (FP). SP duration from both sources (GOG, FP) was collected for 30 trials from a single subject and a regression analysis was performed. HS and TO were identified using a 10N threshold for FP and M±2SD threshold for GOG.
Results: The results showed a high correlation ($r=0.97$, $p<0.001$) between SP duration collected from GOG and FP. In addition, we used the GOG to differenciate different modes of locomotion in terms of velocities and forward versus backward walking. Data were collected from ten healthy subjects (24.7±2.06 years) during walking with two different self selected velocities (slow: 0.91±0.382m/s, fast: 1.89±0.460m/s) and during fast backward walking (1.85±0.203m/s) for 5 minutes. We found significant differences in SP between slow (1.03±0.216s) and fast (0.59±0.105s) walking ($t=3.59$, $p<0.01$), and between forward and backward (0.32±0.067s) walking ($t=10.57$, $p<0.001$).
Conclusions: The GOG has demonstrated that it can correctly identify specific gait parameters and can successfully distinguish between different modes of locomotion. In our future studies the GOG will be used to explore the effect of different pathologies on gait and it will be combined with nonlinear tools for evaluating human gait variability.

WP-52

Feedback torque generation in human eigenvector coordinate

S. Kim and S. Park

KAIST, Daejeon, South Korea

Introduction: We formulated a hypothesis that torque generation could be described by independent eigenvector control.
Methods: Human postural modalities, stereotyped responses, were obtained from the eigenvectors, and modal control input was determined by the linear combination of corresponding modality. To verify the model, postural responses subjected to fast backward perturbation were used. Upright posture was modeled as 3-segment inverted pendulum in sagittal plane, and feedback torque was designed to use each modality independently after the dynamic equation of motion was transformed into the eigenvector coordinate. We used optimization method to obtain eigenvector feedback gains to reproduce both joint angles measured from the postural response and joint torques calculated by inverse dynamics.
Results: Independent eigenvector control showed a good fit ~0.8 in 3-segment simulation, and gain scaling in response to increased perturbations was observed in eigenvector feedback gains. Ankle feedback control decreased with the growing of perturbation magnitude, while hip feedback control increased to accommodate biomechanical constraints on allowable joint torque.
Conclusions: The results suggest that human feedback response using torque generation might be explained by eigenvector control, and the scaling behaviors depending on perturbation magnitudes are showing change of postural strategies from ankle strategy to hip strategy.

WP-53

A quantitative analysis for integration of central and peripheral visual stimuli

H. Park and S. Park

KAIST, Daejeon, South Korea

Introduction: We examined how central and peripheral visual roll rotational signals are integrated in human postural control.
Methods: We applied three test sessions that consist of three visual stimulus trials to 8 young healthy volunteers: 1) central only; 2) peripheral only; and 3) both central and peripheral visual stimulus trials. In each session, subjects stood barefoot with their arms crossed on their chest, and were instructed to keep the balance with their feet flat on the ground. To provide the visual perturbation representing actual roll rotational sway movement, we applied randomly ordered sinusoidal visual stimuli with peak velocity of 13.2deg/sec using 3 sets of LCD monitors. Center of pressure trajectories and tilt perception were measured using force plate and somatosensory bar, respectively. To investigate subjects' perceived roll tilt, they were instructed to indicate their perception using somatosensory bar during each trial.
Results: Roll tilt perception and center of pressure trajectories were in phase with the stimulus, and magnitude of responses decreased as stimulus frequency increased. Postural sway were significantly reduced with absence of peripheral visual stimulus, and peripheral only visual stimulus trials induced larger postural sway than both central and peripheral visual stimulus trials.
Conclusions: The results imply that central and peripheral visions share a weight factor and peripheral vision takes a dominant part for motion sensing.

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W

Y

Z

Conference Participants

Aaslund	Mona Kristin	mona.aaslund@isf.uib.no
Adkin	Allan	allan.adkin@brocku.ca
Akram	Sakineh Beigam	sbakram@ahsmail.uwaterloo.ca
Alexandrov	Alexey	alexeialexandrov@inbox.ru
Allison	Garry	gta@cms.uwa.edu.au
Allison	Leslie	allisonl@ecu.edu
Anaka	Evelyn	evelyn.anaka.1@ulaval.ca
Au-Yeung	Stephanie	rssay@polyu.edu.hk
Azevedo	Christine	christine.azevedo@lirmm.fr
Bair	Woei-Nan	wnbair@gmail.com
Baird	Jennifer	bupt95@kin.umass.edu
Baker	Katherine	katherine.baker@northumbria.ac.uk
Bakker	Maaike	maaike.bakker@fcdonders.ru.nl
Bakshi	Avijit	bakshiavijit@yahoo.com
Balasubramanian	Chitralakshmi	chitra80@phhp.ufl.edu
Barbieri	Guillaume	guillaume.barbieri@u-bourgogne.fr
Barela	Ana	ambarela@gmail.com
Barela	Jose	jbarela@rc.unesp.br
Barthelemy	Dorothy	dorothybarthelemy@gmail.com
Bartsch	Ronny	ronny.bartsch@web.de
Beardsley	Christina	thisisme11@gmail.com
Behrman	Andrea	abehrman@phhp.ufl.edu
Benjuya	Nisim	benjuya@kaye.ac.il
benoit	fourre	benoit.fourre@u-psud.fr
Bent	Leah	lbent@uoguelph.ca
Berard	Jessica	jessica.berard@mail.mcgill.ca
Berrigan	Felix	felix.berrigan@kin.msp.ulaval.ca
Beschorner	Kurt	keb52@pitt.edu
Bloem	Bastiaan	b.bloem@neuro.umcn.nl
Boismier	Thomas	teb1121@yahoo.com
Borel	Liliane	borel@up.univ-mrs.fr
Bowden	Mark	mbowden@phhp.ufl.edu
Boyd	James	james.boyd@vtmednet.org
Brach	Jennifer	jbrach@pitt.edu
Brauer	Sandra	s.brauer@shrs.uq.edu.au
Brown	David	d-brown1@northwestern.edu
Brozgol	Marina	marinab@tasmc.health.gov.il
Brunetti	Fernando	brunetti@iai.csic.es
Brunt	Denis	bruntd@ecu.edu
Buckley	John	j.buckley@bradford.ac.uk
Bugnariu	Nicoleta	bugnariu@yahoo.com
Cacciatore	Timothy	cacci9@yahoo.com
Campbell	Adam	adcampbe@interchange.ubc.ca
Carlson-Kuhta	Patricia	carlsonp@ohsu.edu
Carpenter	Mark	mcarpent@interchange.ubc.ca
Carr	Erin	ec0403@phhp.ufl.edu
Cawsey	Ryan	cawsey@interchange.ubc.ca
Cenciarini	Massimo	mac50@pitt.edu
Cham	Rakie	chamr@upmc.edu
Chambers	April	chambers@engr.pitt.edu
Chapman	Graham	g.j.chapman@bham.ac.uk
Chastan	Nathalien	josiane.sanctot@chu-rouen.fr
Chedevergne	Fany	chedefany@hotmail.com
Chen	Li-Chiou	lichiou@umd.edu
Chernikova	Lyudmila	luda_chernikova@mtu-net.ru
Chiari	Lorenzo	lchiari@deis.unibo.it
Christie	Arrlann	acchrist@sfu.ca
Chvatal	Stacie	stacie.chvatal@bme.gatech.edu
Cinelli	Michael	michael_cinelli@brown.edu
Clark	Sean	sean.clark@gordon.edu
Claus	Andrew	a.claus@shrs.uq.edu.au
Cohen	Helen	hcohen@bcm.tmc.edu
Coley	Brooke	bcc4@pitt.edu
Corbeil	Phillippe	Philippe.Corbeil@kin.msp.ulaval.ca
Corriveau	Helene	helene.corriveau@usherbrooke.ca
Cote	Julie	julie.cote2@mcgill.ca
Couture	Etienne	etienne.couture.2@ulaval.ca
Cowan	Thomas	tomcowan@worldnet.att.net
Creath	Robert	creath@umd.edu
Davis	Justin	jrdavis@interchange.ubc.ca
Day	Kristin	kvday@phhp.ufl.edu
de David	Ana	acdavid@unb.br
de Niet	Mark	m.niet@reval.umcn.nl
Decker	Leslie	ldecker@mail.unomaha.edu
Demont	Richard	rgdemont@gmail.com
den Otter	Rob	a.r.den.otter@rug.nl
Deutsch	Judith	deutsch@umdnj.edu
DiDomenico	Angela	angela.didomenico@libertymutual.com
DiZio	Paul	dizio@brandeis.edu
Dokka	Kalpana	kalpanadokka@hotmail.com
Duclos	Cyril	cyril.duclos@umontreal.ca
Earhart	Gammon	earhartg@wustl.edu
Egerton	Thorlene	t.egerton@shrs.uq.edu.au
Espiau	Bernard	bernard.espiau@inrialpes.fr
Espy	Debbie	despy@uic.edu
Feldman	Fabio	ffeldman@sfu.ca
Ford	Matthew	mford@uab.edu
Frank	James	jsfrank@uwindsor.ca
Fraser	Sarah	sfraser@alcor.concordia.ca
Fujiwara	Katsuo	fujikatu@med.kanazawa-u.ac.jp
Fuller	Jason	fuller.jason2@gmail.com
Fung	Joyce	joyce.fung@mcgill.ca
Gage	William	whgage@yorku.ca
Gagey	Pierre-Marie	pmgagey@club-internet.fr
Galliano	Silvio	silviogalliano@libero.it
Gatts	Strawberry	sgatts@uic.edu
Gaudreault	Nathaly	nathalygaudreault@yahoo.ca
Gdowski	Greg	greg_gdowski@urmc.rochester.edu
Gerin-Lajoie	Martin	martin_gerin-lajoie@brown.edu
Geurts	Alexander	a.geurts@reval.umcn.nl
Gillette	Jason	gillette@iastate.edu
Giraudet	Guillaume	giraudeg@essilor.fr
Godfrey	Adele	agodfrey@uvm.edu
Green	Abbey	abbey.green@gmail.com
Groen	Brenda	b.groen@maartenskliniek.nl
Gross	Melissa	mgross@umich.edu
Gruendlinger	Leor	lgruendl@wisemail.weizmann.ac.il
Hackney	Madeleine	maevisha@yahoo.com
Hall	Courtney	chall7@emory.edu
Hallemans	Ann	ann.hallemans@ua.ac.be
Hamill	Robert	robert.hamill@uvm.edu
Hanna	Maxim	maxim.hanna@mcgill.ca
Hara	Mikiko	haramikiko@aol.com
Hatzitaki	Vassilia	vaso1@phed.auth.gr

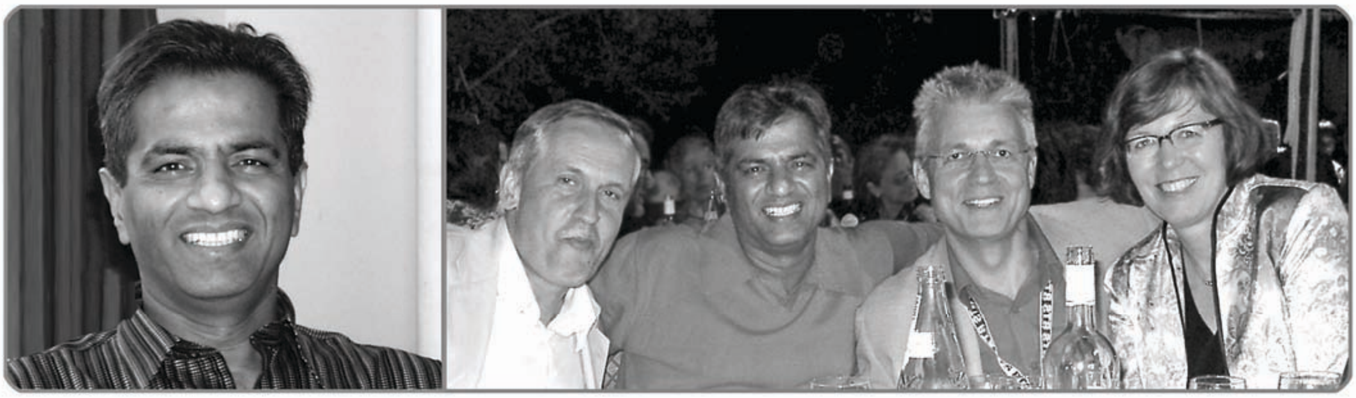
Hausdorff	Jeffrey	jhausdor@tasmc.health.gov.il
Hawken	Malcolm	m.b.hawken@ljmu.ac.uk
Hayashi	Kuninori	kuninory@gmail.com
Heiden	Eric	e.heiden@sympatico.ca
Helbostad	Jorunn Lagdheim	jorunn.helbostad@ntnu.no
Heliot	Rodolphe	rodolphe.heliot@inrialpes.fr
Henry	Sharon	shenry@uvm.edu
Herman Feinstein	Talia	talit@tasmc.health.gov.il
Higuchi	Takahiro	higuchit@comp.metro-u.ac.jp
Hitt	Juvena	juvena.hitt@uvm.edu
Hodt-Billington	Caroline	caroline.hodt@isf.uib.no
Hollands	Kristen	k.hollands@bham.ac.uk
Hollands	Mark	m.hollands@bham.ac.uk
Honeycutt	Claire	claire.honeycutt@gmail.com
Hong	Minna	minna@npg.wustl.edu
Horak	Fay	horakf@ohsu.edu
Horlings	Corinne	c.horlings@neuro.umcn.nl
Hovington	Cindy	cindy.hovington@hotmail.com
Hsiao-Wecksler	Elizabeth	ethw@uiuc.edu
Hughey	Lucinda	lucinda.hughey@mail.mcgill.ca
Ilg	Winfried	winfried.ilg@uni-tuebingen.de
Ishikawa	Kazuo	ishioto@dips07.akita-u.ac.jp
Ivanenko	Yury	y.ivanenko@hsantalucia.it
Jacobs	Jesse	jjacobs@uvm.edu
Jang	John	jang4@uiuc.edu
Janky	Kristen	kjanky@alltel.net
Janssen	Maurice	maurice.janssen@azm.nl
Jasmin	Emmanuelle	emmanuelle.jasmin@mail.mcgill.ca
Jeka	John	jjeka@umd.edu
Jessop	David	david.jessop.1@hotmail.com
Johannsen	Leif	l.johannsen@bham.ac.uk
Johnson	Louise	l.johnson4@bradford.ac.uk
Johnson	Molly	mjohnson@nsm.umass.edu
Jones	Stephanie	stephanie.jones@uvm.edu
Kasser	Susan	susan.kasser@uvm.edu
Kautz	Steven	skautz@phhp.ufl.edu
Keshner	Emily	ekeshner@temple.edu
Kiemel	Tim	kiemel@umd.edu
King	Emily	emily.king@utoronto.ca
King	Laurie	kingla@ohsu.edu
kinugasa	takashi	kinugasa@taiiku.tsukuba.ac.jp
Kizony	Rachel	rachel.kizony@mail.mcgill.ca
Kobayashi	Yoshiyuki	yoshikobo@moegi.waseda.jp
Kueng	Ursula	ukueng@uhbs.ch
kurz	ilan	kurzi@bgu.ac.il
Ladouceur	Michel	michel-ladouceur@uiowa.edu
Lafage	Virginie	virginie.lafage@gmail.com
Lajoie	Yves	ylajoie@uottawa.ca
Langevin	Helene	helene.langevin@uvm.edu
Langhammer	Birgitta	birgitta.langhammer@hf.hio.no
Lee	Tracy	tracy.lee@sri.utoronto.ca
Leroux	Alain	alerou@alcor.concordia.ca
Levin	Mindy	mindy.levin@mcgill.ca
Levine	Thomas	thomas.levine@gmail.com
Li	Karen	karen.li@concordia.ca
Li	Qingguo	qlib@sfu.ca
Logan	David	dlogan@umd.edu
Lowry	Kristin	klowry@iastate.edu
MacLellan	Michael	mjmaclel@ahsmail.uwaterloo.ca
Mahboobin	Arash	arm19@pitt.edu
Mak	Margaret K.Y.	rsmmak@inet.polyu.edu.hk
Maki	Brian	brian.maki@sri.utoronto.ca

Mallau	Sophie	s_mallau@hotmail.com
Mancini	Martina	mmancini@deis.unibo.it
Manfio	Eliane	manfio6@hotmail.com
manorangsan	sukwida	sukwida@unc.edu
Mansfield	Avril	avril.mansfield@utoronto.ca
Marigold	Daniel	daniel.marigold@umontreal.ca
Matheron	Eric	matheron@wanadoo.fr
Mavrommatis	Sophia	sophia.mavrommatis@uclh.nhs.uk
McFadyen	Bradford	brad.mcfadyen@rea.ulaval.ca
McKay	Sandra	sandra.mckay@sri.utoronto.ca
McKinley	Patricia	patricia.mckinley@mcgill.ca
Melzer	Itshak	itzikm@bgu.ac.il
Melzer	Yehudit	meltzer@bgu.ac.il
Menant	Jasmine	jasminem@student.unsw.edu.au
Mercer	Vicki	vmercer@med.unc.edu
Mickle	karen	kjm06@uow.edu.au
Milot	Marie-Hélène	mh.milot@umontreal.ca
Moe-Nilssen	Rolf	rolf.moe-nilssen@isf.uib.no
Moore	Steven	steven.moore@mssm.edu
Muller	Martijn	mtmuller@umich.edu
Muniz	Adriane	adriane_muniz@yahoo.com.br
Murnaghan	Chantelle	cmurnagh@sfu.ca
Murofushi	Toshihisa	murofushi39@yahoo.co.jp
Nadeau	Sylvie	sylvie.nadeau@umontreal.ca
Naing	Veronica	vnaing@sfu.ca
Neptune	Richard	rneptune@mail.utexas.edu
Nerozzi	Erika	erikita73@hotmail.com
Nichols	T Richard	trn@physio.emory.edu
Nien	Yu-Hsiang	yhnien@gmail.com
Nieuwboer	Alice	alice.nieuwboer@faber.kuleuven.be
Noble	Jeremy	jwnoble@uwaterloo.ca
Oates	Alison	aroates@uwaterloo.ca
Ortega	Justus	jdo1@humboldt.edu
Ouckama	Ryan	ryan.ouckama@mail.mcgill.ca
Oude Nijhuis	Lars	l.oudenijhuis@neuro.umcn.nl
Pajala	Satu	pajalass@mail.nih.gov
Paquette	Caroline	caroline.paquette@mail.mcgill.ca
Patritti	Benjamin	bpatritti@partners.org
Patterson	Kara	kara.patterson@utoronto.ca
Pauhl	Katherine	bakerk@interchange.ubc.ca
Pauley	Tim	tim.pauley@westpark.org
Paulus	Isabelle	isabelle.paulus@faber.kuleuven.be
Pearsall	David	david.pearsall@mcgill.ca
Pelland	Lucie	pelland@post.queensu.ca
Perera	Subashan	pereras@dom.pitt.edu
Perry	Stephen	sperry@wlu.ca
Peterson	Carrie	clpeters@mail.utexas.edu
Peurala	Sinikka	sinikka.peurala@sport.jyu.fi
Phillips	Tara	philltar@ohsu.edu
Pinet	Helene	hpinet@sympatico.ca
Platt	Christopher	plattc@nidcd.nih.gov
Plotnik	Meir	meir_plotnik@yahoo.com
Plummer-D'Amato	Prudence	prudence.damato@gmail.com
Prentice	Steve	sprentic@uwaterloo.ca
Preuss	Richard	richard.preuss@mail.mcgill.ca
Redfern	Mark	mgwojnar@pitt.edu
Remelius	Jebb	jebb@kin.umass.edu
Reynolds	Jaimee	jaimee_reynolds@urmc.rochester.edu
Reynolds	Raymond	r.reynolds@ion.ucl.ac.uk
Romanelli	Marco	conancrom@virgilio.it
Rudolph	Katherine	krudolph@udel.edu
Saavedra	Sandy	ssaavedr@uoregon.edu

Salarian	Arash	arash.salarian@epfl.ch
Saracino	Dawn	dsaracin@unf.edu
Sasaki	Kotaro	justkoit@mail.utexas.edu
Schellenbach	Michael	schellenbach@mpib-berlin.mpg.de
Scholz	John	jpscholz@udel.edu
Schulz	Brian	brian.schulz@va.gov
Scovil	Carol	carol.scovil@sri.utoronto.ca
Sebastien	Viel	viel@dpm.cnrs-mrs.fr
Shepard	Neil	njsdizzy@aol.com
Shorter	Kenneth	shorter2@uiuc.edu
Sibley	Kathryn	k.sibley@utoronto.ca
Sihvonen	Sanna	sanna.sihvonen@ktl.fi
Silva	Veronica	vmiyasik@ahsmail.uwaterloo.ca
Simoneau	Martin	martin.simoneau@kin.msp.ulaval.ca
Singer	Jonathan	jcsinger@ahsmail.uwaterloo.ca
Siu	Joseph	ksiu@mail.unomaha.edu
Smeesters	Cecile	cecile.smeesters@usherbrooke.ca
Smulders	Ellen	e.smulders@maartenskliniek.nl
Solomon	David	dsolomon@dizzy.med.jhu.edu
Soo	Caroline	chsoo@sfu.ca
Souvestre	Philippe	pas@neurokinetics.com
Sparto	Patrick	psparto@pitt.edu
springfels	cheryl	cheryl@springfels.com
Stapley	Paul	paul.stapley@mcgill.ca
Stephens	Marilee	mjs74@buffalo.edu
Stephenson	Jennifer	jennifer.stephenson2@mail.mcgill.ca
Stevermer	Catherine	ktsteve@iastate.edu
St-Onge	Nancy	nancy.st-onge@mcgill.ca
Tanaka	Kosuke	kt19801126@hiroshima-u.ac.jp
Tarkka	Ina	ina.tarkka@neuron.fi
Taylor	Denise	denise.taylor@aut.ac.nz
Teasdale	Norman	normand.teasdale@kin.msp.ulaval.ca
Telonio	Alessandro	alessandro.telonio@usherbrooke.ca
Ting	Lena	lting@emory.edu
Tomita	Hidehito	yurayuratommy@yahoo.co.jp
Torres-Oviedo	Gelsy	gelsy.torres@gmail.com
Trombley	Andrea	atromble@uvm.edu
Tsang	Wai Nam William	rswtsang@polyu.edu.hk
Tung	James	james.tung@utoronto.ca
Ushio	Munetaka	izt01356@nifty.ne.jp
Ustinova	Ksenia	ustin1k@cmich.edu
van der Linden	Marleen	m.vanderlinden@reval.umcn.nl
van Nes	Ilse	i.vannes@maartenskliniek.nl
Van Ooteghem	Karen	kvanoote@uwaterloo.ca
van Wegen	Erwin	e.vanwegen@vumc.nl
Vanrenterghem	Jos	j.vanrenterghem@ljmu.ac.uk
Vered	Elisha	elisha@bgu.ac.il
Verheyden	Geert	g.verheyden@soton.ac.uk
Verrel	Julius	verrel@mpib-berlin.mpg.de
Villeneuve	Philippe	ph.villeneuve-ip@wanadoo.fr
Villeneuve	Sylvie	villeneuve-parpay.sylvie@orange.fr
Waddell	Dwight	waddell@olemiss.edu
Wall	James	jcwall@jaguar1.usouthal.edu
Weerdesteyn	Vivian	v.weerdesteyn@reval.umcn.nl
Weiss	Aner	anerw@tasmc.health.gov.il
Wieler	Marguerite	marguerite.wieler@ualberta.ca
Williams	Dorsey	williamsdor@ecu.edu
Winter	David	dwinter@golden.net
Wong	WengHoe	erichw10@doc.med.akita-u.ac.jp
Woollacott	Marjorie	mwool@uoregon.edu
Wright	Rachel	r.wright@worc.ac.uk
Wright	W.	wrightw@ohsu.edu
Wrisley	Diane	dwrisley@buffalo.edu
Yamamoto	Masahiko	masa@med.toho-u.ac.jp
Yoshida	Tomoe	tomoe@med.toho-u.ac.jp
Young	William	wry181@bham.ac.uk
Zabjek	Karl	k.zabjek@utoronto.ca
Zampieri	Cristiane	zampieri@ohsu.edu
Zhang	Yuanfen	yfzhang@umd.edu
Zirges	Sharan	zirges8@cox.net

in Memory

Dr. Aftab Patla



Dr Aftab Patla passed away on January 29, 2007, 8 months after being diagnosed with an aggressive brain tumor. He was a Professor in the Department of Kinesiology at the University of Waterloo. He arrived at the University of Waterloo in 1982 and devoted his research and teaching career to the study of health, aging and human movement. He earned a B Tech in Electrical Engineering from the Indian Institute of Technology (1975), a M.Sc. Eng. in Electrical Engineering from the University of New Brunswick (1978) and a PhD in Kinesiology from Simon Fraser University (1982). During his academic career he served as Executive Editor of the Journal of Motor Behaviour, Associate Editor of the journal Gait & Posture, President of the Canadian Society of Biomechanics and the International Society of Posture and Gait Research and on the Grant Selection Committees of NSERC and MRC. He travelled extensively to talk about his research and was a Visiting Scholar at the University of Otago, NZ and Pennsylvania State University.

Dr. Patla's research provided new insights into how locomotion is generated and controlled in humans. Questions that guided his research included: What aspects of locomotion are pre-planned and stored within the nervous system? What roles do the various sensory modalities play in the regulation of these basic patterns of locomotion in cluttered environments? How do factors, such as dynamic balance, energy cost and stress on tissues, constrain the emergence of a particular pattern? How does development and aging influence the expression of locomotor behaviour? What does it take to be independently mobile in a community? Dr Patla used both experimental and modeling techniques to provide insight into these important problems related to gait and posture.

Many of Dr. Patla's colleagues and students will remember his inventive experiments that attempted to recreate in the laboratory the challenges to locomotion that we face in the natural environment. He published over 200 papers which appeared in psychology, neurophysiology, rehabilitation and aging journals. He was a frequent keynote speaker at international scientific conferences and was known for his entertaining and thought-provoking presentations. One of his former PhD students, now a professor at the University of Western Ontario, wrote: "After leaving Waterloo, I often looked forward to reading one of Aftab's creative papers. I am sad in the knowledge that there will be no more 'Aftab experiments'". While Aftab no longer is here to design the experiments, his passion for and creativity in research will live on through the many students he mentored (22 MSc, 25 PhD and 4 postdoctoral fellows) and his many research colleagues.

During the ISPGR 2007 meeting, the posters with Dr. Patla as a co-author will be presented on Monday, July 16, from 10 am to 12 noon, in the Burlington room. A special tribute seminar and memorial dedicated to Dr. Patla will be held on the same day from 12 noon to 1 pm.