Symposium IX: Sunday June 23, 13:00 - 15:00, Botan

Balance And Gait Disorders: A Symptom-Based Approach

Chair: **Bastiaan R. Bloem**, Radboud University Nijmegen Medical Center, The Netherlands

Chair: **Yasuyuki Okuma**, Juntendo University Shizuoka Hospital, Japan

Careful recognition of neurological gait and balance disorders is very important in everyday clinical practice, for a variety of reasons. First, gait and balance disorders impose significant disability for affected individuals. Second, difficulties with walking and maintaining balance force patients to reduce their physical activities, and physical inactivity is in turn associated with a host of negative consequences, including a worsening of disease symptoms, development of osteoporosis, sleep disorders, and a reduced survival. Third, specific features of gait and balance can offer important diagnostic clues in patients with an uncertain clinical diagnosis. Importantly, changes in gait typically develop early on in the course of many neurological disorders. To improve the clinical recognition of gait and balance disorders, several classification schemes have been proposed. In case of gait disorders, it is a common approach to define the type of gait disorder according to the main presenting feature (1,2). Examples include an ataxic gait, a dystonic gait, or a waddling gait. The typical way of teaching students and residents about such gait disorders is to present a typical phenotype, and to list all the possible features associated with this specific type of neurological gait disorder. However, this is not the way patients usually present to the doctor in clinical practice. Indeed, patients may display only one or at most a few abnormal gait or balance signs, and some of these may fit with different types of neurological disorders. In my presentation, I will offer a new approach to disorders of gait, balance and posture, taking typical presenting features as the starting point for recognising the associated neurological syndrome, and for building a differential diagnosis.

A weak balance, balance and falls in patients with neuromuscular disorders

Corinne Horlings, B.G.M. van Engelen, B.R. Bloem, Radboud University Medical Center, The Netherlands

Both the central and peripheral nervous system contribute to balance control. For studying the influence of the peripheral nervous system on balance control mechanisms, one can examine balance in patients with specific neurological disorders, such as sensory ataxia (due to sensory loss in e.g. patients with polyneuropathy) or muscle weakness. However, in patients with neuromuscular disorders balance is hitherto poorly studied. Even though muscle weakness is an important risk factor for falls, as was shown in the elderly. In patients with neuromuscular disorders, falls are common and clinically relevant. This was shown in patients with fascioscapular humeral disease, who have weakness in both distal and proximal muscles. In a prospective 3 month follow-up, 47% of these patients reported a fall, and injuries occurred in almost 70% of the patients. We also examined the influence of distal versus proximal muscle weakness on balance control, by measuring balance reactions that were probed using sudden platform tilts in different directions in patients with pure distal muscle weakness versus proximal weakness. Here, distal weakness caused greater centre of mass (COM) instability than proximal weakness, and mainly in the pitch plane. Patients with distal weakness also reported greater fall frequency retrospectively. Compensation strategies consisted of increased knee movements and arm movements, which in distal weakness patients were only partly effective. Future studies should focus on formulating muscle weakness thresholds and correlating these with COM instability in order to predict fall risk. Perhaps, rehabilitation for these patients should focus on enhancing compensation strategies in order to prevent falls.

Freezing of gait in Parkinson's disease

Yasuyuki Okuma, Juntendo University Shizuoka Hospital, Japan

Freezing of gait (FOG) is a common and very disabling symptom in Parkinson's disease (PD). It is usually observed in the advanced stage of the disease, although a mild form can be seen in the early stage. FOG occurs more frequently in the off-state than in the on-state. The mechanism underlying the pathogenesis of FOG include sequence effect of a progressive shortening of step length owing to deficient internal driving, impaired automaticity, impaired gait rhythmicity and gait cycle coordination, perceptual malfunction, and frontal executive dysfunction. FOG is considered a result of these multiple gait impairments. Modulation of gait coordination by lateralized (asymmetric) subthalamic stimulation may improve FOG. Walking-through-the-doorway tasks are used to study perceptual malfunction, suggesting that responses to action-relevant visual information are exaggerated in PD with FOG. Falls are also a significant problem in PD patients. FOG is the most common cause of falls in advanced-stage PD patients, particularly in the off-state and transition-state between on and off. Our attempt to objectively evaluate FOG and falls in everyday life using a triaxial accelerometer will be presented.

Imaging and physiological approaches to gait and postural disturbance in Parkinson's disease and related disorders

Takashi Hanakawa, Integrative Brain Imaging Center, National Center of Neurology and Psychiatry, Kodaira, Japan and PRESTO, Japan Science and Technology Agency, Kawaguchi, Japan

The mechanisms of how the central nervous system controls walking and standing remain unclear in humans. The lack of this knowledge makes it difficult to understand the pathophysiology underlying hypokinetic/akinetic-type gait disturbance in patients with Parkinson's disease (PD) and related disorders. Using single-photon emission computed tomography (SPECT), we have demonstrated that gait disturbance is associated with hypofunction of supplementary motor areas (SMA) in PD (Hanakawa et al. Brain 1999) and in patients with ischemic white matter changes (Iseki et al. Neuroimage 2010). Activity in the lateral premotor cortex was negatively correlated with gait disturbance (Iseki et al. Neuroimage 2010). This premotor overactivity was consistent with our previous study in which the premotor cortex showed compensatory activity during paradoxical improvement of gait in PD (Hanakawa et al. Ann Neurol 1999). The roles of SMA and premotor cortex in gait control are also supported by brain activity during planning of gait. Namely, SMA and premotor cortex are active during mental imagery of gait, which is supposed to share mechanisms with planning of actual gait (Iseki et al. Neuroimage 2008). An analysis of diffusion tensor images (DTI) with tract-based spatial statistics indicated that patients with freezing of gait (FOG) had reduced integrity of the white matter beneath the premotor areas (Iseki et al., in preparation). These results consistently support the roles of SMA and premotor cortex underlying control of walking. Patients with PD show abnormal posture during standing, such as camptocormia. To clarify its pathophysiological mechanisms, we have started to investigate muscle activity in the abdominal and trunk muscles on a tilt table (Furusawa et al. 2nd Joint World Congress of ISPGR and Gait and Mental Function). We have found evidence indicating that abnormal muscle activity in the external oblique muscle of the abdomen may trigger the abnormal posture. It would be interesting to examine neural activity in the central nervous system responsible for this phenomenon. Future integration of basic neurophysiology, clinical, and imaging studies will advance the understanding of control mechanisms of gait, and enhance the understanding of pathophysiology of hypokinetic/akinetic gait and postural abnormality.

Symposium I: Monday June 24, 10:00 - 12:00, Hisho A

Advanced Technologies to Enhance Sensorimotor Integration in Postural Control

Chair: **Joyce Fung,** McGill University, Canada

A mixed reality system for sensorimotor rehabilitation

Joyce Fung, McGill University, Canada

BACKGROUND AND AIM: In the control of upright balance, the central nervous system has to generate task-specific and goal-directed motor responses based on the selective and rapid integration of sensory information from multiple sources. Loss of upright balance control resulting in falls occurs frequently post stroke. Postural imbalance may arise not only from motor or sensory impairments but also from the inability to select and reweight pertinent sensory information. Virtual reality (VR) technology provides the opportunity to manipulate sensory, perceptual and cognitive information to optimize motor learning. METHODS: A servo-controlled, self-paced treadmill is mounted on a 6-degree-of-freedom motion platform to simulate sudden or gradual terrain changes. Subjects walk in a virtual environment (VE) that presents challenges related to physical (obstruction and surface angle), temporal (speed requirements to avoid collision with moving obstacles) and cognitive (attention, planning) domains. Subjects also walk with a leash in hand with haptic forces controlled in 3D by a robotic device (Haptic Master). Postural reactions and adaptations during walking are assessed by comparing body kinematics and centre of mass (CoM) trajectories between healthy and post stroke individuals. RESULTS: Persons with stroke generally have difficulty coordinating and stabilizing their body movements when they were first exposed to walking in the VE, as evidenced by their CoM excursions which show less coordination and lack the smooth multiphasic control observed in healthy subjects. However, postural adaptations occurred after repeated exposures and the improvements were retained by training. Increased forward haptic forces result in increased gait velocity and decreased COM excursions, indicating increased postural stability. CONCLUSIONS: A mixed reality system incorporating VR, surface perturbations and augmented haptic input can be utilized for balance and gait rehabilitation post stroke. Balance and gait stability can be improved with repeated practice and training with enhanced somatosensory inputs.

Using Virtual Reality for cross-modal adaptation of whole-body postural control

W. Geoffrey Wright, Temple University, USA

BACKGROUND AND AIM: Sensori- and visuo-motor adaptation has been shown in many forms over the last century. For example, VOR can be directionally recalibrated by prolonged pairing of optic flow with an inertial input that is different than would normally occur (i.e. cross-axis adaptation). Adaptation can also be induced when reaching while wearing prism goggles. After a short period of visually-guided reaching, endpoint errors disappear. But evidence of the visuo-motor adaptation can be seen by aftereffects; when the goggles are removed reaching errors occur in the opposite direction. These adaptations may also be retained over long periods of time, since repeated-exposure may induce fast context-specific adaptation that can be recalled quickly when goggles are donned again. The current study investigates adaptation to discordant visual-inertial input to determine 1) whether virtual environments (VE) can be used to induce whole-body postural adaptation, 2) what spatial and temporal characteristics of the stimulation may affect adaptation, and 3) whether adaptation can be retained. METHODS: Pilot testing (n=8) involved a 6 min period of adaptation during which subjects viewed a VE scene depicting 5m of sinusoidal A/P translation while standing on a surface translating sinusoidally along the M/L axis (left/right: ±10cm) with frequency matched to that of the VE scene (0.2 Hz). After adaptation, COP aftereffects were measured by removing sinusoidal M/L surface input, but continuing A/P sinusoidal optic flow. RESULTS: During adaptation, the A/P optic flow entrained COP in the A/P direction while M/L

COP became entrained with M/L sinusoidal surface motion. The postural response adapted to this combined motion during exposure, i.e. cross-modal adaptation, which was evident in the postural aftereffects. The axis of COP sway was ~45° between the A/P and M/L axes if subjects viewed only A/P optic flow without M/L surface input. A sine fit regression at the 0.2 Hz driving frequency showed a significant increase in sinusoidal M/L COP sway ($p<0.05$) and a significant increase in power spectral density at 0.2 Hz. Nonlinear analysis revealed highly significant differences between A/P and M/L COP pre- and post-adaptation ($p<0.001$). The aftereffect had largely decayed within a few minutes. CONCLUSIONS: After cross-modal adaptation, sensorimotor recalibration ensures postural stability is controlled in the new sensory environment. Nonlinear changes in COP complexity reflect CNS dynamics that drive the sensorimotor integration process to reduce error signals caused by discordant sensory stimuli. Our next experiment will use repeated exposure to cross-modal stimulation to determine if adaptation can be induced more quickly and retained for longer periods. If this experimental paradigm can be used to adapt the sensorimotor system towards a more optimal state, then this would be beneficial outside of the VE (e.g. in rehabilitation interventions).

Technology enhanced sensorimotor integration supports training of postural performance

Emily Keshner, Temple University, USA

BACKGROUND AND AIM: The human balance system relies on multimodal sensory inputs, and the integration of concurrent sensory information with expected sensory consequences. Conflict between sensory signals requires an ability to identify the mismatch, and select an appropriate response. A reduced ability to detect or compensate for this sensory conflict may contribute to the increased incidence of falls during multitasking. Adding noise to a biologic system has been shown to enhance the detection and transmission of weakened or sub-threshold cutaneous signals. It was hypothesized that augmenting proprioceptive information through vibrotactile stimuli would reduce the impact of a visual/vestibular mismatch on postural behavior. METHODS Sub-threshold vibration noise was applied at the soles of the feet in 21 healthy adults (20-29 yrs) standing quietly and performing a mental calculation task on a compliant surface. For both tasks, subjects viewed a virtual scene referenced to their head motion or rotated in upward pitch at 30 deg/sec. An ellipse fit to the covariance matrix revealed excursion of center of pressure (COP) and center of mass (COM) responses in frontal and sagittal planes. RMS values and approximate entropy of the COP and COM were calculated and statistically compared. A training paradigm used sub-threshold vibratory noise applied to the plantar surface of the feet can alter postural behaviors in 5 adults with stroke (39-67 yrs) standing in the dark on a sway referenced support surface. Before, immediately after, and two weeks following this training, postural responses of adults with stroke were assessed in a virtual environment. Pitch upward and downward rotations of the visual field were combined with the sway-referenced support surface. RMS and power spectral density of the COP was calculated. RESULTS: Postural sway was increased with both visual field rotations and mental calculation in a head referenced visual field. Adding mental calculation to visual field rotations, however, decreased postural sway. Adding vibration decreased the area of COM motion and increased regularity of both the COP and COM. COM and COP responses were larger during and after vibration suggesting that both the stabilizing effect of a head-referenced visual field and the destabilizing effect of visual rotation decreased with the administration of vibration. Immediately after and 2 weeks post-training, COP magnitude was decreased and frequency content of the response was more complex than prior to training. CONCLUSIONS: Results suggest that sub-threshold vibrotactile stimulation produced significant effects on the human balance system in environmental conditions that generated increased postural instability. The addition of vibrotactile stimulation modified the direction and regularity of the sway response supporting its use as an adjunct to interventions for impaired balance.

Functional near-infrared spectroscopy as an evaluation and possible training tool for postural control and balance

Masahito Mihara, Osaka University, Japan

BACKGROUND AND AIM: Postural control requires complex visuo-sensorimotor coordination, and previous animal studies have revealed that multiple CNS structures, including the spinal cord, brainstem, cerebellum, basal ganglia, and cerebral cortex, regulate the autonomic and voluntary control of posture and gait in a hierarchical manner. However, human bipedal posture and gait are unstable in nature, and presumably, the cortical contribution is much more important in humans than in quadruped animals. Functional near-infrared spectroscopy (NIRS) could enable us to measure cortical activation during dynamic movements, including gait and postural maintenance, and provide novel insight into the neural mechanism underlying gait and postural control in humans. METHODS: To investigate the cortical activation associated with the maintenance of upright posture in healthy subjects, we applied external postural perturbation by using combined brisk sliding of a platform for 4 cm. We also investigated the correlation between individual balance ability and regional cortical activation (cross-sectional study) as well as longitudinal cortical activation changes and correlation between balance recovery and cortical activation changes (longitudinal study) in post-stroke hemiplegic patients. RESULTS: In healthy subjects, both prefrontal cortices were activated on postural perturbation. A foregoing warning cue provided 2 s before perturbation could enhance the postural perturbation-related cortical activation in the supplementary motor area (SMA) and the posterior association cortex. In post-stroke patients, the SMA activity was correlated with individual balance ability and balance recovery after stroke. CONCLUSIONS: These results indicated that the SMA and posterior association cortex might play important roles in intentional postural maintenance in healthy subjects. Additionally, both cross-sectional and longitudinal study revealed that the SMA was one of the crucial cortical area for balance recovery after stroke. FUTURE DIRECTIONS: In addition to providing unique advantages as a neuroimaging tool for investigating neuronal mechanisms underlying balance and postural control, functional NIRS could be applied as a treatment tool for enhancing motor function or functional recovery. Recently, we have reported the potential usefulness of functional NIRS-mediated neurofeedback as a novel non-invasive neuromodulation technique. A combination of neurofeedback provided using a functional NIRS system and mental practice with motor imagery could enhance the motor imagery-related cortical activation and could augment the recovery of hand movement after hemiplegic stroke. Using similar neurofeedback techniques, we are trying to investigate the therapeutic effect of functional NIRS-mediated neurofeedback on the balance and postural ability in healthy subjects and patients with neurological diseases.

Symposium II: Monday June 24, 10:00 - 12:00, Hisho B

Physical Activity Monitoring With Focus On Physical Behaviour

Chair: **Jorunn L. Helbostad,** Norwegian University of Science and Technology, Norway

Measurement of free-living physical behaviour by use of activity monitors has typically focused on intensity and energy expenditure and their relation to health variables. Another option is to describe physical behaviour in term of postures, transitions and activities that are actually performed, like lying, sitting, standing, walking and transitions between sitting and standing. Such events can be expressed as total time or numbers of events or patterns of activity. More knowledge about different outcomes of activity events can give insight to the role of patterns of daily physical behaviour on functioning in daily life. In the symposium a framework for measurement of physical behaviour by use of activity monitoring will be presented and discussed. Different methods to describe activity patterns will be presented in addition to data on physical behaviour patterns in healthy populations and elderly patient populations.

Event-based analysis of Physical Behaviour: Application in patients with Intermittent Claudication

Malcolm Granat, Caledonian University, Scotland

It has been shown that event-based analysis of physical activity and sedentary behaviour can provide a flexible and yet robust method of producing relevant outcome measures addressing specific clinical, or public health, research questions. The quantification of the patterning of these events can be considered as a direct measure of the physical behaviour of interest. This approach can be illustrated in patients with Intermittent Claudication who report they have to stop regularly whilst walking due to ischaemic pain. Event-based analysis of these walking events can produce clinically-relevant outcomes reflecting symptom severity and its impact on mobility and physical behaviour. These outcomes provide an objective patient-centred measure of disease severity and efficacy of intervention. This flexibility of this approach makes this technique applicable across a wide range of different research constructs.

Physical activity as a dynamical behaviour. - A new paradigm

Sebastien Chastin, Caledonian University, Scotland

Influencing behaviour to enabling and encouraging individuals to maintain and increase their physical activity is a major goal of rehabilitation and public health. This requires that we understand physical activity behaviour and how individuals construct their activity pattern. Currently physical activity is defined as movement leading to energy expenditure. Therefore, energy expenditure and total amount of activity are the principle measurands and outcomes studied and reported. Little attention has been paid to the analysis of patterns of physical activity. Patterns of physical activity are a direct reflection of behaviour and the human decision making process and how people are active; "when people decide to do what". Advances in technology, now enable us to track physical activity patterns over long periods and with great details. The availability of such intensive data logging different domains of physical behaviours will increase rapidly in the future. This is an opportunity to further understand physical activity, but it requires a change in paradigm and an alternative definition of physical activity as behaviour leading to movement and in turn energy expenditure should be adopted. Time series of recorded events enables us to analyse and study the dynamics and diversity of behaviour. We will present clinical examples that illustrate the benefits, technical and analytical challenges of a dynamical approach to the analysis of physical activity data.

Physical behaviour and function in older persons after hip fracture

Kristin Taraldsen, Norwegian University of Science and Technology, Norway

Each year 9000 persons experience a hip fracture in Norway. Hip fractures are associated with high morbidity and mortality, and few regain their pre-fracture function. Older adults with hip fractures represent a large group of older persons with mobility limitations. So far, the only available knowledge about physical activity comes from questionnaires. Because most physical activity in these frail older people is through low-intensity every-day life activities, more knowledge about physical behaviour in real life settings in daily life is needed. Knowledge about physical behaviour may help us understand more about factors contributing to explaining lack of return in pre-fracture function, as well as giving us more information about effects of different treatment approaches. Results from an RCT designed to assess the effect of a geriatric comprehensive assessment and intervention compared to treatment in an orthopaedic ward will be presented. Results on physical behaviour described as length of bouts of activity and activity pattern through the day will be presented. Data on physical behaviour will be compared to outcomes of physical function the 5th day after surgery, and 4 and 12 months after surgery.

The relationship of fatigue with patterns of daily physical behaviour among older adults

Thorlene Egerton, Norwegian University of Science and Technology, Norway

Fatigue is one of the most common reasons given by community-dwelling older people for activity restriction and is a frequently reported as a cause of disability. Not all fatigue among the elderly can be explained by the higher levels of co-morbidities and poly-pharmacy with increased age. Non-specific, self-reported fatigue may be related to an accelerated aging process. Fatigue may be the first sign to emerge of the frailty syndrome, and may therefore be present before the onset of consequent disability and morbidity. In contrast to persistent, non-specific feelings of fatigue, fatigue following physical or other types of activity is to some degree a normal experience. If, however, the level of fatigue experienced after activity relative to the amount of activity performed is exaggerated, it may also be disabling. Activity-related fatigue has been termed 'fatigability', and is a function of de-conditioning as well as the ageing process. Higher levels of both self-reported non-specific fatigue and fatigability may lead to changes in temporal characteristics of physical activity behaviours as well as total amounts of physical activity. Physical activity behaviour quantification can lead to a deeper understanding of problems and their consequences. Data will be presented on the associations between self-reported, non-specific fatigue and fatigability with temporal patterns of daily physical behaviour of 70-75 year olds.

Symposium III: Monday June 24, 10:00 - 12:00, Botan

Disturbances of posture, gait, and space orientation by vestibular dysfunction

Chair: **Toshihisa Murofushi**, Teikyo University School of Medicine, Mizonokuchi Hospital, Japan

We maintain our body balance by integrating vestibular, proprioceptive, and visual information in the central nervous system (CNS). Therefore, dysfunction of the vestibular system including CNS leads to disturbances of posture, gait and space orientation. In this symposium speakers present how peripheral and central vestibular dysfunction affects posture, gait, and space orientation from various viewpoints. Dr. Omi will talk about gait analysis using tactile sensor in vertigo and vestibulospinal tract disorders. His talk will include analyses of patients with central nervous system disorders as well as peripheral vestibular disorders. Dr. Fujimoto will talk about contribution of vestibular dysfunction to postural disorders in the elderly. In postural disorders of the elderly vestibular dysfunction plays an important role. He will talk about both aspects of diseases in the elderly and aging-related dysfunction. Dr, Young will talk about animal study of vestibular-evoked myogenic potentials. Vestibular evoked myogenic potential (VEMP) is one of useful clinical tests of the otolithic system. For better understanding of this test, animal experiments are important. I will talk about disorders of space orientation due to vestibular dysfunction, especially dysfunction of the otolithic organs, sensors of linear acceleration. Because the otolithic organs sense translation and tilt, dysfunction of these organs seems to lead to illusion of tilt and linear movement. I will present dysfunction of the otolithic organs could cause this type of illusion using VEMP. In our study patients with illusion in the roll plane showed tendency of abnormal responses in oVEMP testing, which is a test of the utricle. On the other hand, patients with illusion in the pitch plane showed tendency of abnormal responses in cVEMP testing. On the basis of our findings, I will propose a new clinical entity, idiopathic otolithic vertigo.

Gait Analysis using Tactile Sensor in Vertigo and Vestibulospinal Tract Disorders

E. Omi, Akita University, Japan

Background and aim: Normal gait can only be achieved by systematic integration of normal equilibrium function, space orientation and cognitive function. However, unilateral vestibular disorders such as vestibular neuritis and acoustic tumor, cause defect of space orientation and lead to abnormal gait. To understand, physiologically, how vestibular disorder might affect the stability of gait, normal individuals and patients with various types of vestibular lesion were studied by means of gait analysis using tactile sensors. Methods: 23 normal individuals, 14 vestibular neuritis patients, 61 acoustic tumor patients, 12 spino-cerebellar-degeneration (SCD) patients 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. In addition, stability of foot pressure progression and trajectories of center of force were also be analyzed. Comparison of means were made using the two-tails t-test, with $p<0.05$ as the criterion for statistical significance. Results: Gait instability is depicted by increment of coefficient of variation of each gait phase. 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 TCOF 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 TCOF, significantly longer trajectories were found especially when compared to vestibular neuritis. Conclusions: Vestibular inputs play an important role in the regulation of gait phase. However, gait is in some cases seemed to be normal despite of vestibular dysfunction due to the compensation by visual inputs. In conclusion, gait analysis by the use of foot pressure sensor could provide useful information for the understanding of gait abnormality caused by vestibular disorders. It is desirable to perform the gait test for evaluation of gait abnormality with vertigo patients.

Animal study of vestibular-evoked myogenic potentials

Y.H. Young, Taiwan University, Taiwan

Aim: The otolithic organs, utricle and saccule, respond to linear acceleration and gravity, serving as a functional role in maintaining postural stability. Recently emerging ocular and cervical vestibular evoked myogenic potential (oVEMP and cVEMP) tests expand the test battery for clinicians to assess the dynamic utricular and saccular functions, respectively. This study applied the oVEMP and cVEMP tests to guinea pigs coupled with morphological examination to study the pathophysiology of otolithic disorders in guinea pigs. Method: Ten healthy and 10 gentamicin-treated guinea pigs were enrolled. An amount of 0.05 mL of gentamicin (40 mg/mL) was directly dropped onto the round window membrane of the left ear. After two weeks, all animals underwent oVEMP and cVEMP tests. The oVEMP test was elicited via a hand-held bone-conducted vibrator placed on the animal's forehead at the stimulus intensity of 139 dB force level (FL). The cVEMP test was conducted using click stimuli (120dBSPL) generated by an earphone connected via a short tube inserted into the ear canal. Having finished the VEMP testing, all the animals were sacrificed for morphological study. Results: All 10 healthy guinea pigs exhibited clear oVEMPs, with the mean nI latency, pI latency and nI-pI amplitude of oVEMPs were 3.21±0.39 ms, 4.80±0.29 ms, and 67.3 ±47.8 ìV, respectively. Similarly, all healthy animals showed clear cVEMPs, with the mean positive peak I latency, negative peak II latency, and amplitude I-II of cVEMPs of 6.41±0.78 ms, 7.42±0.52 ms, and 5.75±1.95ìV, respectively. In contrast, none of the gentamicin-treated ears showed clear oVEMPs and cVEMPs. Morphological study of animals with absent oVEMPs and cVEMPs identified substantial damage to the utricular and saccular macula. Conclusion: The animal models of oVEMP and cVEMP in guinea pigs set the stage for studying the pathophysiology of otolithic disorders.

Contribution of vestibular dysfunction to postural disorders in the elderly.

Chisato Fujimoto, University of Tokyo, Japan

Posture in human beings is maintained by muscular actions under the control of the central nervous system. The processing of central nervous system organizes the information from vestibular, visual, and somatosensory inputs. Aging process declines in numerous sensory and motor functions and it is well known that postural stability decreases with age. In general, even though the peripheral vestibular function is damaged by vestibular disease, the prognosis of unsteadiness in the non-paroxysmal period is thought to be favorable when vestibular compensation is established. However, especially in the elderly, there are many cases that suffer from prolonged symptoms due to age-related changes associated with the postural control system, such as poor vestibular compensation and muscle weakness. Postural instability of the elderly with a vestibular dysfunction is considered to be influenced by not only functional impairment of the peripheral vestibular system due to vestibular disease but also age-related degenerative changes of the entire postural control system including the peripheral vestibular system.

The vestibular contribution to spatial orientation in virtual and real environments

Klaus Jahn, Ludwig-Maximilians-University of Munich, Germany

Patients with complete vestibular deafferentation (BVF) show a gait disorder characterized by worsening in darkness and on uneven ground, oscillopsia during walking, and a speed dependency with particular impairment at slow gait velocity (Schniepp et al. 2011). It is less well known, however, that they also exhibit spatial orientation deficits. Patients with BVF after bilateral neurectomy show deficits in virtual spatial orientation tasks and have a reduced hippocampal volume (Brandt et al. 2005). Recent experiments have shown that BVF patients are not able to use an internal map to find shortcuts in a complex real environment. The latter experiments have been combined with functional neuroimaging (FDG-PET) with tracer injection during the navigational task. Further, subjects carried a head-camera throughout the experiment to document their visual exploration behaviour. Results show that patients with BVF have a significantly higher metabolism of the posterior parahippocampus whereas controls activate the anterior hippocampus. Analysis of visual exploration behaviour indicated a landmark-based navigation strategy in BVF. We performed a meta-analysis on central sensory contributions to locomotion and navigation and found support for the hypothesis that visual and vestibular pathways are partly separated in the hippocampal formation (Hüfner et al. 2011). Vestibular functions involve the anterior part of the hippocampus and entorhinal cortex; visual functions the posterior part of the parahippocampal gyrus. In general, it can be assumed, that the lack of vestibular information in patients impairs the construction of a spatial cognitive map via head direction and place cells in the hippocampus, which is compensated by visually-guided parahippocampal navigation. Brandt T, Schautzer F, Hamilton DA, Brüning R, Markowitsch HJ, Kalla R, Darlington C, Smith P, Strupp M (2005) Vestibular loss causes hippocampal atrophy and impaired spatial memory in humans. Brain 128: 2732-2741. Hüfner K, Strupp M, Smith P, Brandt T, Jahn K (2011) Spatial separation of visual and vestibular processing in the human hippocampal formation. Ann N Y Acad Sci 1233: 177-186. Schniepp R, Wuehr M, Neuhaesser M, Kamenova M, Dimitriadis K, Klopstock T, Strupp M, Brandt T, Jahn K (2012) Locomotion speed determines gait variability in cerebellar ataxia and vestibular failure. Mov Disorders 27: 125-131.

Symposium IV: Wednesday June 26, 10:00 - 12:00, Hisho A

Rehabilitation Update

Chair: **Fay Horak**, Oregon Health and Sciences University, USA

Chair: **Prof. Futoshi Mori**, Yamaguchi Unviersity, Japan

Locomotor Mobility following Traumatic Brain Injury

Bradford J. McFadyen, Laval University, Canada

Locomotor mobility (LM) involves the coordination of different aptitudes across cognitive, psychosocial and motor domains. A Traumatic Brain Injury (TBI), regardless of severity, often affects LM at the core of all of these domains. While gait and postural control research for acquired brain injuries such as Stroke has received great attention, TBI research is still in its relative infancy. Yet, all ABIs can benefit from a more systemic understanding of mobility. This talk will address what is understood about LM following TBI and provoke discussion about where it should go to aid diagnoses, prognostication and intervention.

Functional Electrical Stimulation for Restoration of Gait

Yoichi Shimada, Akita University School of Medicine, Japan

BACKGROUND AND AIM: Restoring independence in performing daily functions is the main goal in treating paralytic patients. Recent advances in computer technology has made it possible to control paralyzed muscles by electrical stimulation. We have used functional electrical stimulation (FES) to restore the paralyzed muscles in the upper and lower extremities since 1990. Here we descibe the clinical application of FES in paralytic patients and evaluate the clinical results.

METHODS: Paraplegia for spinal cord injury and hemiplegia for stroke were participated in this research. Two type of electrodes, percutaneous intramuscular electrodes and surface electrodes have been used for stimulation of motor points in paralyzed muscles.

RESULTS: The hybrid-FES using percutaneous intramuscular electrodes provide practical ambulation in paraplegics. Although all paraplegic patients could stand and walk with hybrid FES using percutaneous intramuscular electrods, the clinical results of maximum duration of continuous standing and maximum distance of continuous walking were shown with the hybrid-orthosis using in daily living. The hemiplegic patients with intramuscular electrodes or surface electrodes could walk easily rather than Ankle-Foot Orthosis only. New FES system using surface electrodes, Bioness H300, was mostly effective and practical for restoration of hemiplegic gait.

CONCLUSIONS: FES was useful for restoration of gait in paraplegic or hemiplegic patients. In particularly, Bioness H300 FES system was strongly recommended for clinical use.

Rehabilitation Update: Parkinson Disease

Gammon M. Earhart, Washington University, USA

BACKGROUND AND AIM: This presentation will discuss rehabilitation in Parkinson disease (PD), with an emphasis on treatment of postural instability and gait disorders. The aims of the presentation are to discuss current practices in the rehabilitation for PD, review recent research in the field and the implications of this work for the future, highlighting areas where additional research is needed.

METHODS: A multimedia presentation will be used to illustrate current and emerging evidence supporting various approaches to PD rehabilitation.

RESULTS: As the importance of physical activity and exercise in the management of PD becomes increasing apparent, new models of PD care that incorporate rehabilitation from the earliest stages of the disease are emerging. This presentation will review recent evidence supporting pharmacology, surgery and exercise in the context of multidisciplinary rehabilitation for individuals with PD.

CONCLUSIONS: Participants will come away with a broad overview of the current state of rehabilitation for PD, knowledge of recent developments in the field and recognition of areas where additional research is needed.

Vestibular PREHAB enhance recovery and long time postural performance after planned vestibular lesions.

Måns Magnusson, Lund University, Sweden

An acute vestibular loss results in tonic and dynamic vestibular symptoms with behavioural consequences. Over time these symptoms weaken by action of central nervous compensation, that can be speeded up by vestibular rehabilitation. A simultaneous or previous central nervous disease may however, delay or impede compensation. In planned lesions as in schwannoma suregery or in vestibular ablation in incapacitating Menieres disease, the lesion can be forseen and planned. By introducing pre treatment with vestibular training before the lesion and separating lesion and thus compensation in time from the surgical trauma compensation can be achieved before f ex suregery This process we have named vestibular PREHAB.

We wanted to investigate whether pre-surgical deafferentation would affect post-surgery postural control also in a long-term perspective (6 months). Tot that end 41 patients subjected to trans-labyrinthine schwannoma surgery were divided into 4 groups depending on the vestibular activity before surgery (with no clinical significant remaining function n= 17; with remaining function n=8), whether signs of central lesions were present (n=10), and if patients with remaining vestibular activity were treated with gentamicin with the aim to produce uVD before surgery (n=6). The vibratory posturography recordings before surgery and at the follow-up 6 months after surgery were compared.

We found that the subjects pretreated with gentamicin had significantly less postural sway at the follow-up, both compared to the preoperative recordings and to the other groups.

By combined careful sensory training and separating the surgical trauma and the effects of uVD in time, can adaptive processes develop more efficiently to resolve sensory conflicts, not only resulting in a reduction of symptoms directly after surgery, but also persistent in the longer run and evident at least up to 6 month.

Symposium V: Wednesday June 26, 10:00 - 12:00, Hisho B

Visual dependency and balance control

Chair: **Adolfo Bronstein**, Imperial College London, England

From the point of view of controlling balance visual input is ambiguous as it can signal motion of the subject within the visual environment or motion of visual objects in relation to the subject. This ambiguity is partly resolved by inputs from inertial sensors such as the vestibular and proprioceptive systems. When signals from the inertial systems are unreliable, e.g. due to vestibular or proprioceptive lesions, subjects react excessively to motion of the visual surroundings. This has been documented with postural experiments with moving rooms or projected optic flow and psychophysically with the rod-and-disk test (which measures how much the subjective visual vertical is tilted by concurrent roll axis visual motion). Patients with vestibular disorders are highly sensitive to such visual stimuli but usually recover after the acute phase. However, some patients continue to exhibit enhanced responses to visual motion (so called enhanced visual dependency) and develop visually-induced dizziness (or visual vertigo; Guerraz et al; Brain 2001; 124:1646-56). Recent data will be presented showing that patients with migraineous vertigo have reduced adaptation to repeated visual motion stimulation, which may partly explain their dizzy symptoms (Agarwal et al; J Neurol 2012; 259: 1117-1124). Also, we will show that a laptop version of the rod-and-disk test to measure visual dependency in unselected vestibular neuritis patients can predict long term clinical outcome. Visual dependency is a maladaptive strategy which is detrimental to clinical recovery. Perceptual visuo-vestibular mechanisms, presumably cortical, participate in the long term recovery process after acute vestibular lesions.

The effects of fear and anxiety on human balance control

Mark Carpenter, University of British Columbia, Canada

Fear and anxiety are emotions that are commonly experienced by older adults and those with movement disorders. Strong associations between fear of falling and falls have been previously established, and a growing body of evidence supports a direct relationship between negative emotional state and postural control. Fear and anxiety have been manipulated experimentally through changes in environmental threat, changes in social context, or through the presentation of visual stimuli known to initiate negative emotional responses, in order to quantify the short term effects of emotional changes on postural control. Results indicate that fear and anxiety have significant but, in some cases, differential effects on postural control during static balance and dynamic responses to postural perturbations. Efforts to identify the potential mechanisms through which changes in emotional state may influence postural control have revealed both spinal and supra-spinal contributions, and changes in muscle spindle sensitivity and vestibular reflex gain. This presentation will review recent evidence in support of a causal effect of negative emotional state on human postural control, and the potential mechanisms that may mediate anxiety-related changes in balance performance.

A fully integrated model of threat assessment, vision, and postural control

Jeffrey Staab, Mayo Clinic, USA

BACKGROUND AND AIM: For more than 140 years, clinical observations, clinical research, and physiologic investigations have examined various aspects of the relationships among anxiety, attention, vision, posture, and gait. For the most part, these studies have conceptualized anxiety as a consequence of vestibular and gait disorders or as a disruptive influence on visuo-spatial processing and gait. This presentation argues that threat assessment is a fully integrated and indispensable component of spatial orientation and locomotor control at all times and in all situations in health and disease. METHODS: Studies investigating anxiety disorders and vestibular disorders; state anxiety, response to visuo-spatial stimuli and postural control; trait anxiety, resilience, and recovery after

vestibular insults; and the neuroanatomy of threat, visuo-vestibular, and locomotor control systems in the brain were reviewed. RESULTS: In normal individuals and patients with visuo-vestibular deficits, balance problems, or anxiety disorders, the tendency to be more or less reactive to motion stimuli and perceived postural threat drives locomotor control strategies, conscious attention to gait and posture, clinical symptoms, and functional impairment. CONCLUSIONS: Threat assessment is an inherent element of spatial orientation and locomotion. Anxiety is not a separate cause or consequence of posture and gait problems. Models that fully integrate threat assessment into locomotor control are needed to advance physiologic studies, clinical research, and patient care.

Symposium VI: Wednesday June 26, 10:00 -12:00, Botan

Predicting disease: Is gait a useful biomarker?

Chair: **Jeffrey Hausdorff,** Tel-Aviv Sourasky Medical Center, Sackler School of Medicine, Israel

Lynn Rochester, Newcastle University, England

Gait is emerging as a sensitive tool to discriminate incipient pathology with increasing evidence for its role as a biomarker of healthy ageing and disease. Evidence however is largely from studies in the oldest old. Evidence to support the sensitivity of gait to detect early pathology at the prodromal stage and as a tool to discriminate pathology and aid diagnosis is still accumulating, as are the optimal set of gait characteristics and testing protocols. This symposium aims to explore the evidence with respect to the following: Is it possible to detect prodromal disease with gait; do gait characteristics discriminate pathology; do dual task protocols and increased speed add value for discrimination and prediction?

Predicting Disease: Is Gait A Useful Biomarker?

Anat Mirelman, Tel-Aviv Sourasky Medical Center, Israel

Gait disturbances play a major role in the motor manifestation of many neurodegenerative diseases. Alterations in the gait pattern frequently observed include decreased gait speed, decreased stride length, increased stride-to-stride variability and decreased arm swing. These changes are already apparent in recently diagnosed patients. However, neurodegenerative diseases are known for their long pre-diagnosis phase. Disturbances in smell, sleep, autonomic functions and affect have been reported long before motor changes appear. As such, it is likely that sub-clinical gait alterations are also present in the pre-diagnostic, prodromal phase of neurodegeneration. However, uncovering these changes is challenging as it requires the use of sensitive measures in populations at risk. The objective of this talk is to provide evidence of subtle gait alterations in asymptomatic healthy first degree relatives of patients with Parkinson's disease who are carriers of the G2019S mutation in the LRRK2 gene, subjects who have a heightened risk of developed the disease. In addition, we will explore other motor function abnormalities in populations at risk of neurodegenerative diseases and discuss possible compensatory mechanisms that might mask motor changes in the prodromal phase of disease.

Gait as an early marker of pathology and clinical outcomes: A cross pathology approach

Brook Galna, Newcastle University, UK

BACKGROUND: Subtle gait deficits in the early stages of disease can provide important information about the mechanisms by which different pathologies impact on functional mobility, and can help identify those at greater risk of both motor and non-motor decline. METHODS: This presentation will focus on the commonalities and differences between three distinct pathologies (Parkinson's disease, Spinocerebellar ataxia and Mitochondrial disease) across a range of gait characteristics. RESULTS: By examining how gait differs within and between the three pathologies as well as controls, we show that discrete measures of gait: i) are sensitive to

subtle changes of motor function in the earliest stages of Parkinson's disease and in pre-clinical Spinocerebellar ataxia; ii) can discriminate between specific genotypes of mitochondrial disease and controls, even in patients who present with phenotypically normal gait on clinical observation; and iii) are sensitive to individual pathological mechanisms, manifesting as distinct patterns across the five domains of gait for each pathology. Finally, we show that gait deficit in early pathology is predictive of deleterious health outcomes, such as falls and cognitive decline. CONCLUSIONS: Gait should be considered a sensitive tool to help us draw inferences about underlying mechanisms of pathology, provide a clinically relevant outcome to assess the effectiveness of interventions and monitor disease progression, and potentially identify patients most at need of early intervention.

The role and value of dual task balance and gait tests for fall prediction in older people

Stephen Lord, University of NSW, Australia

Dual or secondary task paradigms have been used to explore the attentional requirements of balance control. The premise is that when two tasks are performed simultaneously that require more than the total information processing capacity of a person, performance on either or both tasks deteriorates. Studies have shown that the attention required for balance control increases with the increased complexity of the balance task, the more complex nature of the cognitive task, increased age and reduced balance abilities.

Dual task paradigms have also been included in fall risk factor studies conducted in older people. Some of these studies have demonstrated that dual task cost (i.e. the difference in balance abilities with and without a secondary task) is a significant risk factor for falls. There is conflicting evidence however, as to whether the addition of a secondary cognitive task to a balance or gait test aids in fall prediction over and above balance and gait tasks undertaken under standard conditions. This presentation will summarise findings of studies that have used dual task paradigms in fall risk factor studies undertaken in older people and clinical groups such as those with Parkinson's disease and cognitive impairment. Findings from a systematic review and meta-analysis of the comparative value of gait speed conducted under simple and dual task conditions will also be presented.

Symposium VII: Wednesday June 26, 13:15 - 15:00, Hisho A

What startles can tell us about posture and gait control

Chair: **Vivian Weerdesteyn**, Radboud University Medical Centre, The Netherlands

Startling contributions to seated postural responses and audio-spinal reflex pathways in postural control

Tim Inglis, University of British Columbia, Canada

The presentation of a loud startling acoustic stimulus has previously been shown to trigger very rapid but accurate movement responses during reaction time paradigms. The first part of this presentation will review this "StartReact" effect, which has been extensively investigated during simple voluntary limb movements. Secondly, experimental evidence suggests that exaggerated neck muscle responses to transient perturbations consists of combined postural and startle components, and hints at a contribution of startle to the aetiology of whiplash-like injuries. Finally, very recent research has been investigating the contribution of startle stimuli to audio-spinal reflexes. Repeated presentation of loud stimuli, given to the so-called habituated CNS, demonstrate significant but persistent reflexive responses in postural muscles, and these responses may provide a means for investigating the integrity of these descending brainstem pathway contributions that could be involved in postural control.

Startle and Gait

Jacques Duysens, KU Leuven, Belgium

The startle response is a very basic reaction while gait is a basic motor act. When combined these two activities are not always compatible. How is this resolved? It is argued that the nervous system is usually able to integrate startle responses smoothly by modulating the responses in different phases of the gait. This is seen both in normal subjects and in Parkinson patients, but the latter show less habituation. Startle is also able to facilitate gait initiation and obstacle avoidance (start-react). Furthermore it is argued that startle-like responses are much more common than often assumed. Usually startle is related to auditory stimulation but it is also seen with other forms of sensory input, in particular due to somatosensory stimulation (such as following mechanical perturbation or electrical nerve stimulation). In fact, the transition between startle and non-startle is not easily determined, thereby leading to underestimation of the role of startle circuitry.

StartReact effects on dynamic postural control

Mark Carpenter, University of British Columbia, Canada

StartReact involves the involuntary, speeded release of a prepared motor response following the presentation of a startling stimulus. Although commonly used with voluntary movements, recent studies have combined StartReact paradigms with cued and uncued balance perturbations to gain new insight into the way in which dynamic balance responses are prepared and influenced by prior experience. StartReact has also proven effective in identifying the potentially startling characteristics of balance perturbations themselves, and the extent to which they may contribute to first trial effects.

Motor control deficits in CNS diseases - insights from startles

Vivian Weerdesteyn, Radboud University Medical Centre, The Netherlands

When an imperative signal to start moving is combined with a startling auditory stimulus (SAS), reaction times are greatly accelerated. This so-called StartReact effect has not only been demonstrated for simple ballistic movements of the arm, but also for more complex movements, such as gait initiation, obstacle avoidance and sit-to-stance. The shortening of reaction times is hypothesized to be caused by the SAS directly accessing a pre-prepared motor program 'stored' in the brainstem reticular formation (Valls-Sole et al., 2008). It may thus give potential insight into the role of brainstem structures in deficient motor control due to central neurological disorders.

In Parkinson's Disease (PD), difficulties with initiating stepping or gait are common. Deficits in planning and preparation of the preceding anticipatory postural adjustments have been suggested to contribute to these difficulties. Hence, one may expect an impaired StartReact effect on APA latency shortening in PD patients when a cue to start walking is combined with a SAS. Two recent studies, however, demonstrated intact SAS-induced acceleration of the APA, but these were underscaled in magnitude (Rogers et al., 2011; Fernandez-delOlmo et al., 2012). Interestingly, in PD patients with severe freezing of gait an absent StartReact effect has recently been reported for a simple ballistic arm movement, which effect could be restored by pedunculopontine nucleus stimulation (Thevathasan et al., 2011). This exciting observation may help unravel the yet poorly understood pathophysiology of freezing. In patients with corticospinal lesions (e.g. stroke), the cortico-reticulospinal pathway has been proposed as a possible bypass circuit to maintain voluntary motor control, yet at the cost of the commonly observed loss of independent joint control (Ellis et al., 2012). The first results from StartReact experiments indeed provide evidence for a potent reticulospinal drive to both upper and lower extremity muscles in patients with corticospinal lesions. Optimization of the functional exploitation of such a bypass circuit may be an emerging target for future rehabilitation treatment of these patients.

Symposium VIII: Wednesday June 26, 13:15 - 15:00, Hisho B

Body and mind interactions in pain and postural control

Chair: **Paul Hodges**, The University Of Queensland, Australia

BACKGROUND AND AIMS: Although early theories proposed that changes in motor behaviour in pain rely on mechanisms at the spinal cord or lower levels of the nervous system, recent work highlights more complex adaptations with evidence of changes at the highest levels of the nervous system. These include changes in the motor and sensory regions of the brain's cortex and an association with cognitive aspects of pain. Of particular interest, these changes have been identified in association with motor behaviours underlying postural control, which are generally controlled subconsciously. Using a range of experimental paradigms this work has aimed to investigate the relationship between postural motor behaviour in people with low back pain (LBP) and: (i) changes in brain organisation, and (ii) beliefs and attitudes about pain. METHODS: This series of studies involved investigation of people with recurring episodes of LBP and healthy control participants. Outcome measures included: temporal and spatial features of activation of the trunk muscles as a component of the anticipatory postural adjustment associated with rapid limb movements; spatial maps of the motor cortex evaluated with transcranial magnetic stimulation; somatosensory evoked potentials; measures of coordination of movement of the lumbar spine and pelvis; and estimation of mechanical properties of the trunk in response to a small mechanical perturbation. RESULTS: Mapping of the motor cortex has revealed a number of key observations;

(i) Areas of the motor cortex with inputs to trunk muscles are not affected uniformly by acute LBP. Excitability of inputs to muscles that stiffen the trunk is enhanced, whereas inputs to the deeper muscles have reduced excitability; (ii) Cortical representation of deep abdominal muscles is shifted posterolaterally, and the amount of shift is linearly correlated with the temporal delay in activation of these muscles in people with LBP; (iii) Although healthy individuals have two main areas of representation of paraspinal muscles on the motor cortex, this is reduced to one in people with recurring LBP. There is preliminary evidence that this "simplification" of the cortical representation is related to changes in motor behaviour such as the ability to coordinate movement of the lumbar spine and pelvis.

Studies investigating the psychosocial domain have identified that although beliefs and attitudes related to pain are associated with how a person reacts to a painful stimulus they do not appear to explain variance in mechanical properties of the trunk.

CONCLUSION: These studies provide strong evidence for involvement the brain and mind in the adaptation of postural motor behaviour in LBP. The results provide evidence that treatment strategies to optimise motor behaviour are likely to require careful attention to the coordination of muscle activity (rather than generalised changes in activation) and attention to psychosocial features of the LBP experience.

Low Back Pain and Trunk Postural Control

Jaap van Dieen, VU University, The Netherlands

BACKGROUND AND AIM: Postural control of the trunk appears to be affected by low back pain (LBP), which is often attributed to impaired lumbar proprioception. However, reports on effects of LBP on trunk sway in sitting and standing, as well as on the underlying muscle activity in these conditions, are quite inconsistent. In this presentation, I aim to describe a model of trunk postural control that can qualitatively explain these inconsistencies and that may provide guidance for more controlled experimentation. METHODS: An overview of studies on trunk postural control will be given. RESULTS: Maintenance of static trunk posture relies on a combination of intrinsic stiffness of the osteoligamentous spine and cocontracting musculature and feedback control. In recent experiments, we demonstrated that visual, vestibular, tactile and proprioceptive information

each play a role in the feedback control of trunk posture and demonstrated interactions between these sensory modalities. Moreover, interactions between environmental and task conditions and the use of sensory modalities for feedback control of trunk posture were found. These interactions cause differential effects of LBP on trunk postural control when environmental and task conditions are varied. For example, differences between cases and controls and patients are less pronounced in unstable than rigid surface conditions, which may be explained by the smaller role of lumbar proprioceptive information when sitting on an unstable surface, While the above suggests that sensory manipulations and support conditions used in different studies could account for differences in effects of LBP on postural sway between studies, this was not confirmed in a systematic review. Based on the review results, we hypothesized that differences between studies could also arise from competing effects of nociception and fear of pain on trunk postural control. While nociception may disturb proprioceptive feedback and hence cause decreased control over trunk posture, fear of pain or pain-related arousal may lead to increased cocontraction, which may enhance postural control. Data from two recent, large cohort studies provide support for the latter in subjects with LBP, with reduced or similar sway, changes in sway frequency and reduced effects of manipulations of lumbar proprioceptive information compared to healthy subjects, consistent with a 'stiffening strategy'. CONCLUSION; The data presented illustrate that nociception, pain-related cognitions, sensory manipulations, and environmental and task constraints have interacting effects on trunk postural control, which should be taken into account when interpreting and designing studies on LBP and postural control.

Sensory-motor interactions in experimental pain and postural control

Rogerio Hirata, Aalborg University, Denmark

BACKGROUND AND AIM: Pain has strong correlation with self-reported falls in elderly, where the knee is one of the joints most affected by pain in this population. However, the postural instability in this population may also be affected by other factors than pain such as loss of muscle strength and joint flexibility. This presentation aims to bring a series of recent research showing the effects of experimental pain models in healthy subjects. Such models allow unique findings by isolating the effect of pain in different muscles in relation to control and baseline conditions in healthy young subjects with no other impairments. METHODS: Injections of hypertonic saline were applied to the calf muscles, leg muscles (close to the knee joint) and infrapatellar fat pad. The subjects were asked to either keep their balance as quiet as possible for one minute or recover their upright posture as fast as possible after an external or internal perturbation. Force platforms were used to measure the center of pressure excursions (COP). Bipolar surface EMG electrodes were used bilaterally to estimate muscle activation in relevant postural muscles. Kinematic data from the lower limb segments was acquired to quantify the angular position, displacement and velocity. During the conditions with internal perturbations (fast voluntary movements), anticipatory postural adjustments (APAs) were quantified. RESULTS: The results suggest that when compared with pain free conditions, pain in the lower limb decreases postural stability, increasing postural sway and altering muscular activation during quiet standing and when reacting to external perturbation. When the balance was perturbed internally, pain altered the APAs when compared with pain free conditions. CONCLUSIONS: The changes in muscle activity due to pain were not similar between subjects, indicating that a complex sensory-motor mechanism drives postural adaptations during pain. Additionally, the muscular strategies adopted during pain were not optimal for stabilizing balance, which may partly explain the strong correlation between pain and self-reported falls in elderly individuals. Hence, clinical approaches to reduce pain may lead to improvements in balance especially for elderly people reporting pain.

Effects of low back pain on lumber movement and contingent negative variation

Katsuo Fujiwara, Kanazawa University, Japan

BACKGROUND AND AIM: Sit-to-stand movement is distinguished into the following 4 phases: 1) the anterior displacement of the center of gravity of the trunk by forward inclination of the pelvis, 2) the lift of the buttocks by upward displacement of the pelvis, 3) the transform to standing posture by the extension of the knee and hip joints, and 4) the stabilizing standing posture. It is reported that in people with low back pain (LBP), the movement speed of the greater trochanter is transiently delayed from 2) to 3). However, there is little investigation about the movement of lumber lordosis in sit-to-stand movement. For people with LBP, the movement of lumber lordosis would be decreased in order to fix the lumber region. Furthermore, they would be careful to do the sit-to-stand movement, and therefore prepare for directing attention early and strongly to the movement. The investigation of these characteristics would provide the viewpoints that the issues related to the sit-to-stand movement in people with impairment of postural control could be demonstrated including the control property by central nervous system. For the elderly subjects, we investigated the effects of LBP on lumber movement and contingent negative variation (CNV). METHODS: Subjects were 22 community-dwelling and healthy elderly women aged 60-79 years. The number of subjects with and without LBP (no LBP) was 12 and 10, respectively. Based on the subjective assessment of the pain, the subjects with LBP were classified as 2 groups (mild LBP (N=6) and moderate LBP (N=6)). Two force platforms, one for the seat and the other for floor, were used to measure the center of pressure in the anteroposterior direction (CoPap) and vertical force (Fz) during the sit-to-stand movement. Reflective marker was placed from Th12 to S1. Recording electrodes for electroencephalogram (EEG) were affixed to the scalp at Cz, in accordance with the international 10-20 system. Movement task was the sit-to-stand in the S1-S2 paradigm. S1 and S2 were auditory stimuli with a 2-s interval. In response to S2, subjects stood up toward their quiet standing position. They were instructed to respond to S2 as quickly as possible and to stand up at a comfortable speed. This trial was repeated until 20 EEG waveforms without any artifact were averaged. Movement onset time to S2, movement angle of lumber, and CNV peak latency and amplitude were analyzed. RESULTS: Movement onset time was 241 ± 61 ms in no LBP, 198 ± 35 ms in mild LBP, and 290 ± 60 ms in moderate LBP. The onset time in moderate LBP was significantly later than mild LBP ($p < 0.05$). Inter-trial variation of the onset time tended to be larger in moderate LBP, but no significant group difference was found. Lumber lordsis angle before the movement start did not significantly differ among groups. Moderate LBP tended to once flex the lumber region (i.e. rebound action) about 500 ms after the sit-to-stand movement onset, and then start forward inclination of the pelvis. Lumber movement angle tended to be smaller in moderate LBP than the other groups (no LBP: 9.2 ± 4.7, mild LBP: 9.1 ± 4.2 and moderate LBP: 5.6 ± 1.5). CNV peak latency was -421 ± 281 ms in no LBP, -448 ± 334 ms in mild LBP, and -893 ± 168 ms in moderate LBP. The latency was significantly longer in moderate LBP than the other groups. CNV peak amplitude tended to be smaller in moderate LBP, with no group difference (Fig.1). CONCLUSION: These results suggest that in the sit-to-stand movement, the elderly with moderate LBP would early direct their attention toward upcoming movement to comparatively fix their lumber.