



O.1.1 The role of the frontal lobe in complex walking tasks in healthy older adults and patients with Parkinson's disease: An fNIRS study

Inbal Maidan¹, Hagar Bernad-Elazari¹, Freek Nieuwhof², Miriam Reelick², Nir Giladi¹, Judith Deutsch³, Jeffery Hausdorff¹, Anat Mirelman¹

¹Sourasky medical center, ²Radboud University Nijmegen Medical Centre, ³Rutgers Biomedical and Health Science

Introduction Accumulating evidence suggests that gait is influenced by higher order cognitive and cortical control mechanisms. Recently, several studies used functional near infrared spectroscopy (fNIRS) to examine frontal lobe activity during walking, reporting increased oxygenated hemoglobin (HbO₂) levels during walking while dual tasking (DT), compared to usual walking. Previous work also showed that motor-cognitive deficits, like those seen during DT walking, are exaggerated with aging and Parkinson Disease (PD). However, the role of frontal activation during DT walking and during obstacle negotiation, another complex walking task that likely utilizes cortical control, is largely unknown. Here, we aimed to investigate changes in frontal activation during DT and obstacle negotiation between healthy older adults and subjects with PD. Methods 20 healthy older adults (mean age 69.7±1.3 yrs, 50% females) and 47 patients with PD (mean age 71.7±1.1 yrs, 32% females) were studied. Frontal brain activation of Brodman's Area 10 was assessed using an fNIRS system consisting of two probes placed on the forehead of the subjects and gait was assessed using an electronic walkway. Assessments included: walking at a self-selected speed; walking while serially subtracting 3s; walking while stepping over 5 obstacles; and standing while serially subtracting 3s. Data were collected from 5 walks of 30 meters in each condition. Twenty seconds of quiet standing before each walk served as a baseline of frontal lobe activity. Repeated Measures Analysis of Variance tested changes between conditions and groups. Post hoc analysis was used to assess changes between usual walking and the other walking conditions. Results Significant differences were observed in HbO₂ levels between all conditions ($p < 0.001$). No significant differences were seen between groups ($p = 0.79$), however, the HbO₂ level interaction between group and condition was significant ($p = 0.004$). Both groups tended to increase their frontal activation during walking while stepping over obstacles ($p < 0.051$), however, only the healthy older adults increased their frontal activation during walking while subtracting 3s ($p = 0.016$). The healthy older adults had a lower DT cost for gait speed ($p < 0.001$) and better performance of serially subtracting 3s ($p = 0.034$) than the subjects with PD. The HbO₂ level during walking while serially subtracting 3s was correlated with the performance of serially subtracting 3s in the subjects with PD ($r = 0.332$, $p = 0.031$), but not in the older adults ($p = 0.408$). Conclusions This study provides direct evidence that walking while stepping over obstacles is associated with frontal brain activation in both healthy older adults and subjects with PD, while walking while subtracting 3s increased frontal activation only in healthy older adults. It is unclear whether the absence of a change in HbO₂ during DT in subjects with PD is the cause or effect of lower DT performance.



O.1.2 Anisotropy of human vertical and horizontal navigation in real space: behavioral and PET correlates

Andreas Zwergal¹, Florian Schöberl¹, Guoming Xiong¹, Philipp Werner¹, Cauchy Pradhan¹, Peter Bartenstein¹, Christian la Fougere², Klaus Jahn¹, Marianne Dieterich¹, Thomas Brandt¹

¹University of Munich, ²University of Tuebingen

BACKGROUND AND AIM: Previous navigational studies mostly investigated orientation in 2-dimensional space, i.e. in the horizontal plane. However, in everyday live humans often have to find their way in 3-dimensional environments. In the present study, we tested spatial orientation performance, visual exploration and brain activation patterns during a predominantly vertical versus horizontal real navigation task in humans. **METHODS:** Healthy subjects (n=24, mean age: 54 ± 8.9 y) performed a navigation paradigm in a 15-level-staircase (vertical plane) and in an outpatient clinic (horizontal plane) of a hospital. In both paradigms five different items were placed hidden in different locations. During the exploration period the location of each item was shown to the subjects. In the navigation period, subjects had to find the items in a pseudo-randomized order over the next 10 min. All subjects carried a gaze-controlled head-camera throughout the experiment to document visual exploration behaviour. In half of the subjects, [18F]-Fluorodesoxyglucose was injected during the vertical navigation paradigm, in the other half during the horizontal navigation paradigm. As a control condition another [18F]-FDG-PET was done either during horizontal walkway or vertical staircase locomotion without spatial navigation. Brain activation patterns of vertical and horizontal navigation were analysed and compared to navigational performance and visual exploration. **RESULTS:** Spatial orientation was significantly worse during vertical as compared to horizontal navigation ($p < 0.03$). During horizontal navigation subjects executed more eye movements. Horizontal navigation (as compared to horizontal locomotion) induced a prominent increase of regional cerebral glucose metabolism (rCGM) in the right anterior hippocampus, retrosplenial cortex and pontine brainstem tegmentum, vertical navigation (as compared to vertical locomotion) in the anterior hippocampus bilaterally and insula (left>right). Further, comparison of brain activation patterns in both navigation paradigms revealed a significant relative increase of rCGM in the superior vermis, insular cortex (left>right) and anterior cingulate during vertical navigation and of the pontine tegmentum and motion sensitive visual areas during horizontal navigation. **CONCLUSIONS:** The data support a functional anisotropy during real space orientation and navigation in favour of the horizontal versus the vertical plane in humans. The hippocampal formation plays a central role for encoding of space in the horizontal and vertical domain. Horizontal navigation relies predominantly on visual and ocular motor activity, vertical navigation requires vestibular input.

O.1.3 A cerebral dissociation between motor imagery of gait and dynamic balance in Parkinson's disease

Murielle Ferraye¹, Bettina Debû², Fedde Sappelli¹, Mahur Hashemi¹, Mark Carpenter³, Bastiaan Bloem⁴, Ivan Toni¹

¹Radboud University, ²Grenoble Institut des Neurosciences, INSERM U838, Université de Grenoble,

³University of British Columbia, ⁴Radboud University Nijmegen Medical Center



BACKGROUND AND AIM: Gait and balance disorders are poorly understood, yet highly debilitating symptoms of Parkinson's Disease (PD). Gait and postural problems often occur together, suggesting that they might depend on a common pathophysiological mechanism. However, clinical observations and deep brain stimulation studies have shown that freezing of gait can improve without consistent effects on postural instability. This study tests for a spatial dissociation between the neural substrates of gait and dynamic balance, in PD patients and in healthy age matched controls. **METHODS:** We report preliminary results on 9 Parkinson patients with freezing of gait and/or postural instability and 10 healthy age matched controls. These participants performed two recently validated gait and dynamic balance tasks across two levels of control demands. Subsequently, they were asked to imagine performing the same tasks while their cerebral activity was measured with functional magnetic resonance imaging (fMRI). Visual imagery tasks were used to assess the motor specificity of the effects. Subjects reported onsets and offsets of both actual and imagined tasks by pressing a button. The time between the two button presses was taken as the actual or imagined movement duration. **RESULTS:** Imagery durations indicate that the participants implemented different levels of control during motor imagery of both gait and dynamic balance. Task performance was well matched between PD patients and controls. During motor imagery of dynamic balance, control participants showed prominent activity in the supplementary motor area. PD patients showed increased activity in the ventral portion of the mesencephalic locomotor region (MLR). During motor imagery of gait, the dorsal portion of the MLR showed increased activity (figure 1). **CONCLUSIONS:** These results indicate that the frontal cortex and the ventro-lateral part of the MLR play a prominent role in controlling dynamic balance. We suggest that postural instability might emerge in PD when altered cortical control of dynamic balance is combined with a limited ability of the ventro-lateral MLR to react to that alteration. These limitations might become particularly evident in situations at the limit of stability, where the patients would require to take a step in order not to fall. The MLR segregation between gait and dynamic balance might have therapeutic implications, in particular with respect to deep brain stimulation interventions.

O.1.4 Cortical control of human gait function: Similarities and differences in corticomuscular coherence during treadmill walking and overground walking

Luisa Roeder¹, Tjeerd Boonstra², Simon Smith¹, Ian Stewart¹, Graham Kerr¹

¹Queensland University of Technology, ²University of New South Wales

BACKGROUND AND AIM: There is increasing evidence that the cortex is involved in human locomotor control, as revealed by corticomuscular coherence during treadmill walking. Although treadmill and overground walking have similar temporospatial gait patterns in healthy people, differences in kinetic parameters and muscle activation patterns have been observed. In the present study we compare corticomuscular coherence between EEG and EMG from active leg muscles during treadmill walking and natural overground walking to investigate similarities and differences of the transmission of motor cortical activity to the muscle between the two gait modalities. **METHODS:** Six healthy human subjects (mean age 30.1 ± 7.7 years; 1 woman) performed overground walking and treadmill walking at a comfortable, self-selected pace (3.5 - 5 km/h). Spectral analysis was performed according to the theoretical framework described by Halliday et al. (1995) and Rosenberg et al. (1989) and calculated



using the publicly available MATLAB toolbox NeuroSpec 2.0. Pooled coherence was computed between the Cz EEG electrode and the tibialis anterior (TA) muscle of the right leg. Time-dependent coherence was calculated relative to the heel strike of the right foot. RESULTS: During treadmill and overground walking, corticomuscular coherence was significant at 12-25 Hz (alpha, beta) for offsets between -450 ms prior to 50 ms post heel strike. Significant coherence was also observed at lower frequency bands from 2-7 Hz (theta) from -700 ms prior to 50 ms post heel strike during treadmill walking and -800 ms to -300 ms prior to heel strike during overground walking. When comparing both gait modalities, coherence was significantly higher during treadmill walking in theta, alpha and beta frequencies at most times of the gait cycle (-800 ms to -425 ms prior, -275 ms prior to 25 ms post, 125 ms to 200ms post heel strike, $p < 0.01$). CONCLUSIONS: We found similar patterns of significant corticomuscular coherence in beta frequency bands during treadmill walking and overground walking. This suggests that rhythmic cortical activity is transmitted via the corticospinal tract to the active leg muscles in similar manner during both gait modalities. In addition to beta-band coherence, we also observed significant EEG-EMG coherence in frequency bands below 10 Hz, which have not been reported previously. However, we found different levels of corticomuscular coherence during treadmill and overground gait. We interpret the higher coherence levels during treadmill walking as increased cortical control, which may indicate that normal, steady-state overground walking requires less conscious attention than artificially induced treadmill gait. From a clinical perspective, this has important implications for gait function recovery training in individuals with injuries or disease of the central nervous system.

O.1.5 Increased functional connectivity of the central executive network in patients with Parkinson's disease with a history of falls

Keren Rosenberg-Katz¹, Talia Herman¹, Yael Jacob¹, Pablo Bezalel¹, Anat Mirelman¹, Nir Giladi¹, Talma Hendler¹, Jeff Hausdorff¹

¹Tel Aviv Sourasky Medical Center

BACKGROUND AND AIM: Falls are a debilitating problem that impact the quality of life of patients with Parkinson's disease (PD). Several lines of evidence suggest that two mechanisms contribute in parallel to falls in PD: 1) striatal dopaminergic loss leads to reduced automaticity of the motor system; and 2) a decline in attentional resources that are needed for safe ambulation in complex situations such as those required during dual tasking exacerbates fall risk. We speculated, therefore, that poor regulation of the central executive network (CEN) which is involved in divided attention will be associated with falls in PD. METHODS: We assessed functional connectivity using resting state functional magnetic resonance imaging (rs-fMRI) between nodes of the CEN and compared it between patients with PD who were fallers ($n=27$) and non-fallers ($n=53$). The network included the bilateral dorsolateral prefrontal cortex, superior temporal gyrus, posterior parietal lobe and inferior parietal lobe. Striatal gray matter (GM) atrophy in the affected caudate and putamen were evaluated using a voxel-based morphometry (VBM) toolbox. Gait variability, a marker of fall risk, was assessed using body-fixed sensors under usual-walking and while dual tasking. RESULTS: PD fallers had decreased caudal, but not putamen GM volume and increased connectivity within the CEN, especially in partial regions involved in attention, as compared to PD non-fallers. Adjusting for attention or for caudal gray matter volume attenuated this effect. In line



with this finding, the increased connectivity within the CEN was correlated with reduced caudal gray matter volume (selected in the affected caudate head, $p < 0.05$) and with dual tasking ($p < 0.003$), but not usual-walking gait variability ($p = 0.336$). CONCLUSIONS: Among patients with PD, increased connectivity of the CEN is associated with a history of falls and with poorer gait. This increased connectivity may be compensation for gray matter atrophy and loss of automaticity of the motor system.

O.1.6 The integrative role of the pedunculopontine nucleus in human gait

Marie-Laure Welter¹, Brian Lau¹, Hayat Belaid¹, Sara Fernandez-Vidal¹, Eric Bardinet¹, David Grabli¹, Carine Karachi¹

¹Groupe Hospitalier Pitié-Salpêtrière, ICM

Background: The brainstem pedunculopontine nucleus (PPN) has a likely, although unclear, role in gait control, and is a potential deep brain stimulation (DBS) target for treating resistant gait disorders. These disorders are a major therapeutic challenge for the aging population, especially in Parkinson's disease (PD) where gait and balance disorders can become resistant to both dopaminergic medication and subthalamic nucleus (STN) stimulation. Methods: We recorded PPN and STN neuronal activity during a locomotor imagery task in 14 PD patients undergoing surgery for the implantation of PPN or STN DBS electrodes. We performed electrophysiological recordings in two phases, once during surgery, and again several days after surgery in a subset of patients. Results: The majority of PPN neurons (57%) recorded intrasurgically exhibited changes in activity related to different task components, with 29% modulated during visual stimulation, 41% during modulated voluntary hand movement, and 49% modulated during imaginary gait. PPN local field potentials recorded postsurgically were modulated in the beta and gamma bands during visual and motor events, and we observed alpha and beta band synchronization that was sustained for the duration of imaginary gait and spatially localized within the PPN. In contrast, significantly fewer STN neurons (27%) recorded intrasurgically were modulated during the locomotor imagery, with most increasing or decreasing activity phasically during the hand movement that initiated or terminated imaginary gait. Conclusion: Our data support the hypothesis that the PPN influences gait control in manners extending beyond simply driving pattern generation. In contrast, the STN appears to control movement execution that is not likely to be gait specific. These data highlight the crucial role of these two nuclei in motor control and shed light on the complex functions of the lateral mesencephalon in humans.

O.1.7 Increase in frontal brain activation during dual task walking after training using a Smartphone-based biofeedback system in patients with Parkinson's disease: a fNIRS study

Jeffrey Hausdorff¹, Moran Dorfman¹, Hagar Bernad-Elazari¹, Eran Gazit¹, Pieter Ginis², Alice Nieuwboer², Sinziana Mazilu³, Alberto Ferrari⁴, Laura Rocchi⁴, Lorenzo Chiari⁴, Anat Mirelman¹

¹Tel Aviv Sourasky Medical Center, ²KU Leuven University, ³Swiss Federal Institute of Technology,

⁴University of Bologna



Background and aim: In healthy subjects, previous functional near-infrared spectroscopy (fNIRS) studies reported increased levels of oxygenated hemoglobin (HbO₂) levels within the prefrontal cortex, a brain region linked to both cognition and locomotion, during dual task (DT) walking. We assessed the effects of an intensive motor-cognitive training program on frontal lobe activation during usual walking and DT walking in patients with Parkinson's disease (PD). **Methods:** 9 patients with PD (mean age: 69.7±5.5 yrs, disease duration: 9.6±4.7 yrs, 2 women) participated in a 6 weeks at-home training program. Auditory bio-feedback (ABF) training was provided via a new Smartphone-based system (CuPiD). The system measures gait in real-time using wearable sensors placed on each shoe and gives instructions to improve the patient's walking pattern. Subjects trained independently with the system 3 times a week, 30 min each session. Once a week, a therapist conducted a home visit to provide feedback on training progression and to adjust the training parameters. Pre and post training assessments included the evaluation of gait using a gait mat; frontal brain activation was assessed using fNIRS. Subjects walked under 2 conditions: 1) usual walking, self-selected comfortable speed; and 2) DT walking, i.e., while subtracting 3 from a pre-defined 3 digit number. Each walking task consisted of 5 walks of 30 meters. After subtracting local baseline values, the HbO₂ level for each task was determined by averaging the 5 repetitions of the task. Non-parametric tests evaluated differences between pre and post values and between usual walking and DT walking. **Results:** After training, HbO₂ levels during DT increased by 0.35 μ M (p=0.046). No significant differences in HbO₂ levels were observed between usual walking and DT walking, either before or after the training program (p=0.200 and p= 0.337, respectively). Gait variability during dual tasking was lower (more consistent) after training (pre: 3.03% \pm 2.11%, post: 2.39% \pm 1.36%; p=0.008). However, no differences in gait variability during usual walking were observed after training (pre: 2.47% \pm 1.31%, post: 2.43% \pm 1.31%; p=0.859). In addition, significant differences were observed in gait variability before training between usual and DT walking (p=0.008). However, no significant differences were observed in gait variability after training between usual and DT walking (p=0.594). Gait speed during usual and DT walking improved after training (pre: 1.07 \pm 0.18 m/sec, post: 1.21 \pm 0.18 m/sec; p=0.008 and pre: 0.93 \pm 0.16 m/sec, post: 1.11 \pm 0.21 m/sec; p=0.011, respectively). **Conclusions:** After training using the Smartphone-based wearable system for 6 weeks, gait variability was significantly decreased and activation in frontal brain areas tended to be higher. These findings suggest that the effects of the motor-cognitive training resulted in greater ability to perform DT and a greater capacity to increase frontal lobe activation

O.1.8 Brain activity related to stabilizing gait in young and older adults.

Sjoerd Bruijn¹, Nick Kluit¹, Jaap Van Dieën¹, Andreas Daffertshofer¹

¹VU University Amsterdam

Walking on two legs is inherently unstable. Still, we humans perform remarkable well at it, mostly without falling. However, at the extrema of the age spectrum, the unstable nature of bipedal locomotion becomes apparent. At young age, we are unable to walk, and crawl on all fours. At high age, we sometimes return to a quadrupedal gait (with front limbs replaced by walking aids). How we are able to have a stable bipedal gait in between these periods is still a matter of research. Still, the consequences of unstable gait, that is, falls, come with an enormous personal, and socioeconomic



burden on society. To overcome this burden a fundamental understanding of how humans stabilize gait is pivotal. While the influence of peripheral factors on gait stability has received ample attention in the literature, the research on central processing for gait stability is still in its infancy [1]. To gain more understanding of the role of the brain in gait stability over the lifespan, we measured brain activity using Electro Encephalo Graphy (EEG) during stabilized and normal walking in healthy young and older subjects. Subjects walked on a treadmill in two conditions, each lasting 10 minutes; normal, and while being laterally stabilized by elastic cords [2]. Kinematics of trunk and foot clustermarkers were sampled at 100 samples/s by an optoelectronic system (Optotrack, Northern Digital, Waterloo, ON, Canada), and EEG was recorded at 2048 samples/second by means of a 64 channel cap, amplified by a TMSI REFA amplifier (TMSI, Enschede, The Netherlands). To assess differences in gait stability, local divergence exponents were calculated from the kinematic data [3]. The EEG data were preprocessed using Independent Component Analysis (ICA) [4] to remove movement, EMG and eyeblink artifacts, after which source localization (Dynamic Imaging of Coherent Sources) was applied to look for sources that showed a significant difference in activity in different frequency bands. In young subjects, stabilized walking led to significant increases in gait stability (i.e. lower local divergence exponents). Moreover, source localization at the beta band yielded significant sources in bilateral pre-motor cortices, which showed more activity during stabilized than unstabilized walking. Data of the older subjects are currently being analyzed. Our results suggest a role for the brain in regulating gait stability, even in healthy young subjects. We expect this role to be increased in older subjects. Acknowledgments SMB was funded by a grant from the Netherlands Organisation for Scientific Research (NWO #451-12-041). References [1] Bakker et al. (2007) J Neural Transm. 114(10):1323-31. [2] Dean et al. (2007) IEEE Trans Biomed Eng. 54(11):1919-26. [3] Bruijn et al. (2013) J R Soc Interface 10(83). [4] Gwin et al. (2010) J Neurophysiol. 103(6):3526-34.

O.2.1 Both standing and postural threat decrease Achilles tendon reflex inhibition from tendon electrical stimulation.

Brian Horslen¹, J Timothy Inglis¹, Jean-Sébastien Blouin¹, Mark Carpenter¹

¹The University of British Columbia

BACKGROUND AND AIM: Height-induced postural threat has been shown to influence Ia pathways [1], yet the effects on Ib reflexes are unknown. Tendon electrical stimulation (TES) evokes short latency, likely Ib-mediated, inhibition in medial gastrocnemius (MG) in lying subjects [2]; but it has yet to be shown in stance. As such, we performed two experiments to determine the effects of: a) standing on TES reflexes (EXP1), and b) height-induced postural threat on Ib reflexes (EXP2). Based on prior work [3-4], we hypothesized a) TES inhibition would be smaller in stance, compared to lying; and b) inhibition would decrease with greater postural threat. METHODS: EXP1 included 9 young adults; 6 of whom also participated in EXP2. Surface EMG (gain: $\times 1000$, filter: 10-1000Hz) was recorded (2000Hz) from MG and rectified offline. The TES anode was placed on the Achilles tendon at the level of the malleoli and the cathode at the muscle-tendon junction (imaged with ultrasound); 0.5ms square-wave pulses were used. An early inhibitory response (I1) [2] was established while prone, subjects then stood and stimulation intensity was increased (4.5-10x perceptual threshold) to evoke a response in stance; which was used



for all subsequent trials. 100 pulses (1-4s inter-stimulus interval) were used in each condition. In EXP1, subjects performed a quiet stance condition followed by a prone condition (with MG activated isometrically to match stance activity). In EXP2 subjects stood on a hydraulic lift in a LOW (0.8m high, 0.6m from edge), then a HIGH (3.2m, at edge) threat condition. EMG data were trigger-averaged, and mean and SD were calculated from a 100ms pre-stimulus period. Onset, duration, mean and area of inhibition of I1 were calculated and compared between conditions. RESULTS: Onset latencies did not change between prone (mean \pm SE; 47.6 \pm 1.8ms) and stance (45.9 \pm 1.1ms) conditions. There was a trend to a smaller area of inhibition in stance ($p < 0.09$); this was caused by a significantly shorter duration (26.5 \pm 7.1ms shorter, $p < 0.01$), but no change in mean inhibition ($p > 0.4$). On average, duration in EXP2 was shorter in the HIGH, compared to LOW, condition (28.8 \pm 56ms); with no change in area. CONCLUSIONS: The shorter duration of I1 suggests less net inhibition of MG in stance, compared to lying. Likewise, less Ib inhibition has been shown with Hoffmann reflex conditioning in stance, compared to sitting or lying [3-4]. As such, these data support a Ib origin for the I1 period [2], and further demonstrate TES is a viable method for standing experiments. Preliminary data suggest a decrease in Ib inhibition at height. A decrease in Ib inhibition, in conjunction with greater excitatory Ia reflexes [1], would suggest a bias toward excitation in balance-relevant reflexes with threat. REFERENCES: [1] Horslen et al. J Neurophysiol 2013; [2] Khan & Burne Brain Res 2009; [3] Stephens & Yang Brain Res 1996; [4] Faist et al., Brain Res 2006. ACKNOWLEDGEMENTS: Funded by NSERC

0.2.2 The role of hip abductor proprioception in mediolateral balance control of gait in older adults

Mina Arvin¹, Mirjam Pijnappels¹, Marco Hoozemans¹, Gert Faber¹, Bart Burger², Sabine Verschueren¹, Jaap van Dieën¹

¹VU University Amsterdam, ²Medical Centre Alkmaar

Background and aim: Hip abductor muscles play an important role in mediolateral (ML) gait control, but the contribution of hip abductor proprioception in ML gait control is unclear. We studied the importance of hip abductor proprioception in ML balance control of gait in older adults. Methods: Eighteen healthy older adults (71 SD 7 years) walked on a treadmill at their preferred speed in two different conditions: 1) mechanical vibration of hip abductor muscles in randomly 40% of the steps during the early stance phase (earlyST), and 2) during the late stance phase (lateST). Full body 3D kinematic data were collected using cluster LED markers on both feet, shanks, thighs, the pelvis and the trunk segment. Means of step width (SW) and ML margin of stability (ML MOS) were compared by Paired sample t-tests between vibrated and non-vibrated steps; while One-sample t-tests were used to compare averaged differences between vibrated steps and non-vibrated steps for pelvis tilt, hip angles, and trunk COM acceleration over the first double-support (DS), single support (SS) and second DS phases. Results: With earlyST vibration in the DS phase, the pelvis was significantly more tilted up on the ipsilateral side, while contralateral hip adduction increased and trunk COM accelerations towards the contralateral side increased. In the SS phase, the pelvis tilt and stance hip abduction were significantly larger in vibrated steps. Besides, the trunk COM acceleration increased towards the stance side in vibrated steps compared to non-vibrated steps. Overall, the participants walked with the same step width and ML MOS in the vibrated steps. With lateST vibration, initially the pelvis was tilted upward on the ipsilateral side,



with increased ipsilateral hip adduction and trunk COM acceleration towards the ipsilateral side. During the SS, pelvis tilt angles remained increased and also contralateral hip abduction was increased. The trunk COM acceleration significantly increased towards the contralateral side in the second DS phase, while the MOS was decreased in this phase. Conclusions: Vibration in earlyST appeared to cause increased activation of the hip abductor muscles, resulting in pelvis upward tilt, contralateral adduction and ipsilateral abduction and increased trunk COM acceleration towards the contralateral side. The trunk COM acceleration was compensated in the SS phase. The absence of effects on the SW and ML MOS suggest that this compensatory strategy was successful. The lateST hip abductor vibration appeared to cause opposite effects, suggesting a reflex reversal, with increased activation of ipsilateral adductors or decreased activation of ipsilateral abductors. Such a reversal is in line with effects of ongoing motion on movement illusions induced by vibration. The response led to a higher trunk COM acceleration towards the swing leg, which was counteracted in the subsequent late stance. However, this late compensation caused a decrease of the MOS.

O.2.3 Full Body Kinematic Analysis of Altered Vestibular Reflexes Caused by Postural Threat

Jonathan de Melker Worms¹, John Stins², Peter Beek², Ian Loram¹

¹Manchester Metropolitan University, ²VU University Amsterdam

BACKGROUND AND AIM: In elderly, fear of falling is associated with an increased risk of falling. This study is focused on direct effects of fear of falling and vestibular sensory feedback on full body postural control. Using galvanic vestibular stimulation (GVS) increased body sway is induced [1]. Using kinematic data Osler et al. [1] inferred that induced body sway within 800 ms after GVS onset is unaffected by fear of falling, by comparing subjects standing at height and at ground level. Conversely, using a continuous stochastic GVS signal (SVS) and recording ground reaction force (GRF) data, Horslen et al. [2] found two peaks of increased SVS-GRF coupling at height compared to ground at time delays of ~150 and ~300 ms. We aimed to investigate the kinematic mechanism of short latency processes identified in SVS-GRF coupling. Using full body kinematics we investigated the effect of fear of falling on the timing of the GVS response of the whole kinematic chain. **METHODS:** For 16 young healthy adults (10 men and 6 women, age: 25.9 ± 5.1 years, height: 1.74 ± 0.1 m, weight: 69.5 ± 13.5 kg, BMI: 22.9 ± 3.5) vestibular-evoked balance responses were studied while standing on a narrow walkway at ground level and at a height of 3.85 m (Fig. 1A). Full-body kinematics was collected and skin conductance was recorded as a measure of physiological arousal. GVS was delivered following the method of Osler et al. [1]. Subjects' feet were placed together, directed along the antero-posterior axis of the walkway. They stood with eyes closed and head facing directly forward. In each condition 30 GVS impulses of 2 seconds (15 anode-left, 15 anode-right, randomly ordered) were applied at intervals of 20 seconds. **RESULTS:** 1-1.5 s after GVS onset maximum mediolateral displacement of COM was higher at ground level ($t=3.45$, $df=15$, $p=0.004$) than at height (Fig. 1B, lines are averages, shaded areas are 95% confidence intervals). A short (SLP), medium (MLP) and late latency (LLP) COM acceleration peak can be distinguished (Fig. 1C). In the height condition SLP amplitude was increased ($t = -2.15$, $df = 15$, $p = 0.049$) and MLP and SLP occurred earlier compared to ground (MLP: $t = 5.21$, $df = 15$, $p < 0.001$; LLP: $t = 3.39$, $df = 15$, $p = 0.004$). SLP amplitude of mediolateral sway acceleration of the knees was increased at height (Fig. 1D: Anode sided knee: $t = -$



2.27, $df = 15$, $p = 0.039$; Cathode sided knee: $t = -2.74$, $df = 15$, $p = 0.015$). CONCLUSIONS: Increase of early (SLP and MLP) body segment linear acceleration at height was only present in lower extremities. Fear of falling changes the effect of vestibular sensory feedback on lower extremity kinematics during standing and these postural effects become present within a delay of 100 ms. This indicates modification of appendicular vestibular fast reflexive pathways caused by fear of falling. LITERATURE: [1] Osler et al., *Eur J Neurosci*, 38(8), 3239-3247, 2013. [2] Horslen et al. *J Physiol*, 592, 3671-3685, 2014.

0.2.4 Cervical stretch reflexes in normal subjects and bilateral vestibular patients

Adolfo Bronstein¹, Michael Gresty², Paul Strutton², Sofia Nousi²

¹Imperial College London, ²Imperial College

Background Neck muscle motoneurons are innervated by both vestibular and proprioceptive afferents which stabilise the head either on the trunk or in space. Since the majority of body manoeuvres activate both systems simultaneously it is difficult to differentiate their respective properties. The aim of this study was to isolate a neck stretch reflex from the sternocleidomastoid muscle (SCM) with the head fixed in space in order to eliminate vestibular activation. **Methods** The subjects were 17 healthy adults and 8 patients with bilateral vestibular failure. Subjects were seated in a semi-reclined position with a forehead head restraint. Electromyographic (EMG) activity was recorded bilaterally from sternal (SM) and clavicular (CM) heads of SCM. The left SM tendon was tapped using a hand-held electro-mechanical device with subjects relaxed and during voluntary isometric neck flexion. Forehead skull taps were also applied to evoke vestibular responses, VEMPs. Rectified EMG responses were analysed. The nature of the EMG responses evoked by the left SM tendon tap was tested in 10 healthy participants using different head positions. The left SM tendon was tapped when subjects a) were seated in a semi-reclined position and b) were upright seated with 90° head rotation to the right. The forehead was fixed with a head restraint in both conditions. **Results** Seated Reclined Position Tapping the left SM tendon, evoked EMG responses of a similar latency in the ipsi- and contra-lateral SCM muscles in both groups when the neck muscle was relaxed (~32 msec) and isometrically contracted (~33 msec). There were no latency differences between subject groups or between different levels of muscle contraction. The areas of the EMG responses were significantly larger in healthy subjects than in patients. Forehead skull taps (vestibular responses) evoked responses at latencies consistent with vestibular evoked responses (VEMPs) in healthy subjects (~15ms) but not in patients. **Effects of head position** Tapping the left SM tendon evoked responses of similar latencies and sizes in the ipsi SCM muscles (~31 msec) in both head positions. In contrast, contralateral EMG responses were evoked during isometric neck flexion only. There was no significant difference of the pre-stimulus mean, of the left SM, between the two experimental conditions. **Conclusion** Our data indicate that the tendon tap responses in all subjects were induced via neck muscle stretch afferents and not by activation of the vestibular system. The contralateral responses observed in both healthy and BVF subjects suggest that there is a crossed reflex in neck muscles. The relatively long latencies found would suggest a long loop reflex. Presumably this stretch reflex is the substrate of the cervico-collic reflex which norm



O.2.5 Noisy galvanic vestibular stimulation improves dynamic walking stability in healthy subjects

Klaus Jahn¹, Max Wuehr¹, Elisabeth Nusser¹, Siegbert Krafczyk¹, Andreas Straube¹, Thomas Brandt¹, Roman Schniepp¹

¹University of Munich

Background: We examined the effect of galvanic vestibular stimulation (GVS) delivered as zero-mean white noise current (noisy GVS) on the walking performance in healthy subjects. Methods: The walking performance of 15 healthy subjects (mean age 23.0 ± 1.3 years) at slow, preferred and fast walking speed was examined during two different conditions: (1) walking with eyes closed and zero amplitude sham noisy GVS, and (2) walking with eyes closed and non-zero amplitude noisy GVS set to 80% of the individual sensory threshold for GVS. We examined 10 gait parameters: stride time, stride length, base of support, swing time percentage, double support time percentage as well as the CV of stride time, stride length and base of support, gait asymmetry and bilateral phase synchronization. Results: Noisy GVS significantly improved stride time CV by 34% ($p < 0.019$), stride length CV by 26% ($p < 0.048$), base of support CV by 18% ($p < 0.004$), gait asymmetry by 39% ($p < 0.037$), and bilateral phase synchronization by 19% ($p < 0.042$). This ameliorating effect of noisy GVS on locomotion function was only observable during slow walking speeds. Conclusions: Noisy GVS is effective in improving locomotion function in healthy subjects. It predominantly targets the variability and bilateral coordination characteristics of the walking pattern, which are critically linked to dynamic walking stability. The predominant impact of noisy GVS during slow walking supports the principle of a speed-dependent role of sensory feedback in locomotion control.

O.2.6 Precise coding of ankle rotation by lower-limb muscle spindle afferents

Ryan Peters¹, Brian Dalton², Jean-Sébastien Blouin¹, J. Timothy Inglis¹

¹University of British Columbia, ²University of Oregon

BACKGROUND AND AIM: The role of calf muscle spindles in standing balance control has been questioned due to only small, paradoxical muscle movement observed in the ankle plantarflexors during quiet stance. Can calf muscle spindles provide useful feedback on the small ankle movements associated with quiet standing, and are these afferents activated paradoxically (increase firing rate with ankle plantarflexion)? Here we report the findings of ongoing human microneurography experiments investigating the firing properties of lower-limb muscle spindles. We focus primarily on ankle plantarflexor afferents, because only dorsiflexor afferents have been studied in detail previously. METHODS: Nine healthy participants (one female; mean age = 31, SD = 10.5) participated in this study. Muscle spindle afferents were recorded from the tibial nerve ($n=12$) with participants laying prone, and from the common peroneal nerve ($n=3$) with participants sitting on an adjustable chair. Currently our dataset consists of 5 muscle receptors from the lateral gastrocnemius, 1 in the medial gastrocnemius, 4 from the soleus, 2 from the intrinsic foot muscles, and 3 from the tibialis anterior. When a muscle



spindle afferent was identified, the participant's foot was loaded into an actuated ankle plantarflexion-dorsiflexion device instrumented with a load cell (JR3 1000N125) to reproduce the vertical ground reaction forces present during standing balance. Participants were exposed to continuous ankle plantarflexion-dorsiflexion movements with a power spectrum replicating that of quiet standing (max. peak-to-peak amplitude = 0.7°; bandwidth = 0 to 0.5 Hz; mean power frequency = 0.28 Hz). RESULTS: Although ankle loading in the microneurography setup only approximates actual standing (mean load = 18 kg; SD = 11 kg), we argue that this protocol offers critical insight into whether muscle afferents are even capable of coding for the natural ankle oscillations that are characteristic of quiet standing. Ankle movement coding was indexed as a significant level of coherence for at least one frequency component contained within the stimulus. Three-quarters of the muscle spindles (9 out of 12), particularly those located in the soleus muscle (4 out of 4), exhibited instantaneous firing rates that correlated with ankle angle during at least one trial. Soleus had the highest peak coherence on average, as well as the broadest bandwidth of significant coherence. CONCLUSIONS: These results suggest that a sub-population of calf muscle spindles are poised to play an important role in the standing balance control loop. In addition, all responsive muscle spindles increased their firing rate with ankle dorsiflexion. The lack of paradoxical spindle behaviour could be because participants only made low-level isometric contractions and were not required to balance an unstable load.

O.2.7 Contribution of plantar-surface mechanoreception in recovery from a slip

Stephen Perry¹, Rachel Billo¹, Jessica Berrigan¹

¹Wilfrid Laurier University

BACKGROUND AND AIM: Plantar-surface mechanoreceptors provide us with information about the surfaces we are walking on. The overall function of plantar-surface cutaneous receptors is to sense pressure distribution under the foot and to encode changes in forces between the foot and contact surface. Since the foot's plantar surface is the first and usually only point of contact with the environment, the information from cutaneous receptors are important in regulating balance responses during gait. This experiment will further investigate the importance of plantar-surface cutaneous receptors in detecting and responding to an unexpected slip during walking. METHODS: Twenty young adults (20-23 yrs old) participated in this study. These were 10 control and 10 test group participants who had reduced plantar-surface sensation (via hypothermia ice submersion). Reduced sensation was confirmed using Semmes Weinstein monofilaments to determine touch thresholds measured in grams (g) of force (control 0.98 g versus test group 32.9 g, $p < 0.01$). Unexpected slips were induced by placing waxed paper beneath high friction sand paper that was usually secured to the force platform's surface. Two consecutive slips were randomly presented within multiple walking trials (at least 5 trials occurred prior to the slip trials) and these were used for analysis. Muscle activity was recorded from the tibialis anterior and medial gastrocnemius of the slipped limb to determine activation magnitude and timing. Kinematic markers were placed on the participants to track foot displacement during slips. All trials were performed barefoot. RESULTS: Both groups had similar number of forward slips. In the forward slips, only 3 of 10 in the control group were considered severe slips (foot displacement > 0.1 m) whereas the test group (reduced sensation) had 6 of 9 severe slips. Additionally, both groups had a burst of tibialis



anterior muscle activity during the midstance of the slipped foot that is not typical during a regular gait cycle. The tibialis anterior (of the slipping leg) activation onset for the control group (19.8% of the right stance phase) was significantly earlier than that of the test group (48.7%, $p < 0.05$). The slip distance for the most severe slips were smaller for the control group compared to the test group (reduced sensation) (0.2 m vs. 0.3 m), but this result did not reach statistical significance. **CONCLUSIONS:** The control of muscle activity immediately after foot contact during slipping trials may be critical to reduce the severity of a slip. Also appropriate sequencing of muscle activity, as triggered by the detection of loading patterns under the foot, may also be important to reduce the severity of the slip. These findings indicate that the plantar-surface sensation may play an important role in detecting the severity of the slip and also providing critical sensory feedback in order to produce appropriately scaled balance responses from the lower limb muscles.

O.2.8 DETECTING THE HEIGHT OF THE GROUND UNDERFOOT

Marie-Laure Mille¹, Joanna Offord², Richard Fitzpatrick²

¹Toulon University, ²Neuroscience Research Australia

Background and aim. Sensory knowledge about the height of the ground underfoot is essential for adjusting posture and movement to optimise balance and locomotion. This study aimed to determine thresholds for detecting changes in the height of the ground during standing and walking and identify sensory and motor processes involved. **Methods.** In a psychophysical threshold tracking protocol, subjects ($N = 8$) reported whether the right foot, on a variable platform, was higher or lower than the left foot (Fig A). Thresholds for detecting differences in ground height were measured while: (i) supported upright but not standing, (ii) standing, (iii) taking a single step to a different height, or (iv) walking and taking the final step to a different height. Proprioceptive contributions to this sense were explored by tendon vibration (100 Hz) over m. tensor facia lata (TFL) unilaterally. Vestibular contributions were explored by binaural bipolar galvanic vestibular stimulation (GVS, 1 mA). Thresholds were compared with foot clearance while walking, measured using a motion analysis system. **Results.** While supported upright, 50% detection was achieved with ~ 9 mm difference in ground height (Fig B). This was not different if the experimenter or the subject positioned the feet (passive vs active) (8.4 ± 1.9 mm [95%CI] vs 9.6 ± 2.5 , $P = 0.18$). Free standing reduced the threshold by 38% (5.8 ± 0.90 , $P = 0.003$). Perceptions were idiosyncratic. Across subjects, passive, active and standing thresholds were correlated ($r = 0.77$ to 0.83) and bias (i.e. slope perceived as level) ranged ± 6 mm with bias in the passive and active conditions correlated ($r = 0.85$). Vibration over TFL resulted in the ground on the ipsilateral side being sensed lower (3.3 ± 1.1 mm, $P < 0.001$), or an $\sim 1^\circ$ slope. GVS (+R -L) resulted in the ground under the right foot being sensed lower (3.1 ± 1.3 mm, $P < 0.006$) with subjects supported upright (Fig C). They also reported left tilt and thus sensed that the body was bent to the left. When standing freely, the ground effect was not present (0.8 ± 1.5). Instead, the body leaned right taking a typical bent posture. Thresholds increased when taking a single step (8.5 ± 2.4) but were significantly lower (54%) when walking 5 steps before stepping to the different height (3.9 ± 0.6 , $P = 0.004$). TFL vibration had no effect during stepping and walking. In only 8.8% of the measured steps (15/176) did foot clearance fall below the detection threshold and, across subjects, mean foot clearance was positively correlated with its



variance ($r = 0.86$, $P = 0.006$). Conclusions. During standing, proprioceptive and vestibular signals interact to create the sense of ground height and body orientation. During locomotion the timing of sensory afference relative to expectation at footfall provides the dominant signal of ground height. The control of ground clearance during locomotion is organised around knowledge of the sensory acuity and motor variability.

O.3.1 The Development of Trunk Control and its Relation to Reaching: A Longitudinal Study

Jaya Rachwani¹, Victor Santamaria¹, Sandra Saavedra², Marjorie Woollacott¹

¹University of Oregon, ²University of Hartford

BACKGROUND AND AIM: The relationship between the development of sitting postural control and of reaching during infancy has not been addressed in detail. It has recently been shown that infants progressively learn to control an increasing number of trunk segments for the acquisition of upright sitting, starting with the head, then the upper trunk and subsequently the lower/pelvic regions. However, previous studies on infant reaching evaluated infants during supported supine or reclined sitting positions, failing to address the contributions of distinct segments of the trunk to reaching. In this study we provide an external support at different levels of the trunk during reaching to examine the mechanisms by which segmental trunk control impacts reaching across development. **METHODS:** Ten healthy infants (5 males and 5 females) were recruited at the age of 2.5 months and were tested longitudinally, twice a month, until the age of 8 months. The effects of stabilizing the upper and lower regions of the trunk were assessed by providing vertical trunk fixation at two regions of the trunk (thoracic and pelvic), during a seated reaching task. Kinematic and electromyographic documentation of posture and reaching movements reflected how control of the free regions of the trunk modulated both behaviors. During each session, infants were also assessed with the Segmental Assessment of Trunk Control (SATCo) to determine the intrinsic level of trunk control acquired. **RESULTS:** Results showed that during the months prior to acquiring full trunk control, infant reaches were faster, straighter and smoother with a higher support at the thoracic level compared to when the support was limited to the pelvic level. In addition, infants displayed less sway, associated with decreased paraspinal muscle activity with thoracic support. Once infants acquired full trunk control, they no longer required the help of a higher support to produce coordinated reaching. Thus, differences in reaching performance, postural stability and neuromuscular activity between thoracic and pelvic levels of support were not observed after achieving complete trunk control. **CONCLUSIONS:** Results reinforce and further expand previous findings showing that improvements in trunk control have direct consequences on the development of reaching. With the help of additional support during the maturation of trunk control, infants experience substantial improvements in their reaching skills and subsequent muscular parameters. This relationship between reaching and trunk control should also be examined in children with postural deficits. More studies are needed to examine both the potential benefits of the use of specific external trunk support and the efficacy of implementing graduated levels of trunk support in therapeutic strategies for improving manual abilities in children with trunk postural disability.



O.3.2 The effects of practice and disuse on quadrupedal gait in infants, children, and adults

Whitney Cole¹, Beatrix Vereijken², Jesse Young³, Scott Robinson¹, Karen Adolph¹

¹New York University, ²Norwegian University of Science and Technology, ³Northeast Ohio Medical University

BACKGROUND AND AIM: As the old saying goes, you never forget how to ride a bike. But despite extensive research on skill acquisition, we know little about the effects of disuse on skill in later life. Quadrupedal crawling provides an ideal case for the study of the effects of disuse; although most Western infants crawl habitually during the first year of life, virtually all later abandon it in favor of walking. And although children and adults may briefly revert to crawling when the situation calls for it, crawling never again becomes their predominant form of locomotion. The aim of the current study was to describe the effects of practice and disuse on quadrupedal gait. **METHODS:** We observed crawling in 27 11- to 12-year-old children and 13 college-age adults who had not crawled in decades. We compared these "rusty" crawlers to two groups of habitual crawlers: 34 infants with 0.1-5.5 months of crawling experience, and a unique group of 5 adult siblings from a remote region of Turkey whose primary form of locomotion was crawling (video provided by the BBC). Infants, children, and college-age adults crawled over a laboratory walkway; the habitual adult crawlers were filmed during normal daily activities (M=7 crawling sequences each). Coders scored the timing and placement of steps frame-by-frame from video. Sequences of steps were then categorized into quadrupedal gait types according to definitions from the animal literature. **RESULTS:** Infants crawled faster with crawling experience, $p < .05$. But surprisingly, lack of recent experience did not hinder older children: Normalized for body size, children crawled faster than infants and college-age adults, $p < .01$, and displayed astonishing forms of quadrupedal coordination--running with periods of two, three, and all four limbs in the air. Moreover, both groups of rusty crawlers spontaneously produced a variety of crawling patterns, including gaits surprising in crawling humans. They paced (moved limbs on same side of body together) in 30.6% of strides and used asymmetrical gaits such as galloping like a horse (12.3% of strides) and bounding like a squirrel (.8% of strides). In contrast, infants and habitual adult crawlers favored symmetrical, trot-like gaits that afford greater stability (71.7% of strides). **CONCLUSIONS:** Children and adults assembled unusual quadrupedal gait patterns on the fly. Despite years or even decades of disuse, both groups of rusty crawlers were able to successfully coordinate four limbs into effective locomotion. Although habitual crawlers were less impressive in terms of speed and flight time, they favored more stable patterns of coordination (such as trots) and avoided potentially unstable or extremely strenuous gaits (such as paces or bounds). In conclusion, both rusty and habitual crawlers are capable of effective crawling. Only habitual crawlers, however, show evidence of optimizing crawling for daily use.



O.3.3 Adults with Autism Spectrum Disorders do not use vision for postural control.

Susan Morris¹, Chris Foster¹, Torbjorn Falkmer¹, Richard Parsons¹, Marita Falkmer¹, Simon Rosalie¹

¹Curtin University

BACKGROUND AND AIM: Autism Spectrum Disorders (ASD) are common neurodevelopmental disorders characterized by atypical social interaction and behaviors. A comorbid movement disorder is commonly reported. Evidence suggests that children with ASD rely more on proprioceptive than visual information when learning reaching movements. However, the reliance on proprioceptive information in ASD in quiet standing, remains unknown. In quiet standing in typically developed adults (TDI) with adequate vision, proprioceptive information is down-weighted over visual information. This can be observed by the amelioration of a vibration induced postural illusion when shifting from an eyes closed to an eyes open condition. The present study investigated the relative importance of visual and proprioceptive information in quiet standing in ASD using a postural illusion induced by neck vibration. It was hypothesized that adults with ASD would retain a preference for proprioceptive information. **METHODS:** The participants (12 ASD, 20 TDI) stood on a force plate (AMTI, Watertown, MA) (1000Hz) 1.5 meters from a white wall with black horizontal line at eye height. 'Anterior/posterior movement of the Center of Pressure' (COPY) was measured over 4 trials. Each trial consisted of 15 seconds of quiet stance (no vibration) followed by a 5 second pulse of dorsal neck vibration (100 Hz, VB 115, Techno Concept, Cereste, France), the cycle repeated 10 times (=200 seconds). Vision was manipulated using liquid crystal spectacles that could be changed from translucent to opaque (PLATO, Model P1, Translucent Technologies Inc., Toronto, ON, Canada). The trial type was named by the visual condition in the no vibration and vibration periods (visual occlusion = NV - vision available = VA). Four trials (NV-NV, VA-NV, VA-VA and NV-VA) were conducted in a randomized order. **RESULTS:** Significant main effects were observed for group, $p < .05$, vibration illusion $p < .0001$, and visual occlusion condition, $p < .01$. For both ASD and TDI the magnitude of COPY during vibration under visual occlusion was 40 mm. A significant interaction was also observed between group and visual occlusion condition, $p < .0001$. The ASD group leaned forwards more than the TDI group when vision was either fully available or available for either the vibration or non-vibration period (VA-VA, VA-NV, NV-VA $p < .01$); whereas, there was no difference in COPY between groups when vision was not available (NV-NV $p = 0.527$). There were no differences in the COPY of the ASD group regardless of whether vision was fully available or available for either the vibration or non-vibration period or not available at any time ($p > 0.0335$). **CONCLUSIONS:** Unlike TDI, adults with ASD did not use vision to modify an illusion created by proprioceptive input. This finding suggests that adults with ASD are not using visual information to inform postural control which may explain differences in movement in this group.



O.3.4 Gymnastics skill level affects sensory reweighting processes during quiet stand in children.

Albert Busquets¹, Silvia Aranda-Garcia², Blai Ferrer-Uris¹, Michel Marina¹, Rosa Angulo-Barroso³

¹Institut Nacional d'Educació Física de Catalunya - Barcelona, ²Universitat de Girona, ³California State University Northridge

BACKGROUND AND AIM: The relative contribution of sensory inputs to control balance may change due to perturbations (alterations in sensory inputs) or reweighting (alterations may cease). Age effects in sensory integration and balance control have been reported. In addition, expertise capability (skill level) could also impact balance control, especially in individuals who practice a sport that emphasizes equilibrium as artistic gymnastics. It was suggested that adult gymnasts were able to regain balance control faster than non-gymnasts possibly due to a more efficient reweighting process. No studies have examined skill level effects on the sensory reweighting processes in children. This study aims to investigate the capacity of children with different gymnastic skills levels to adjust standing posture (with eyes open, EO, and eyes closed, EC) during and after a proprioceptive perturbation (tendon vibration).

METHODS: 45 children (age= 9.4 ± 1.3 years) divided based on their gymnastics skill level took part in this study: non-gymnasts (NG, n=12), intermediate-gymnasts (IG, n=21), and advanced-gymnasts (AG, n=12). Two identical vibrators (frequency=85 Hz, amplitude=1mm) were bilaterally strapped at the Achilles tendon level. Participants stood quietly on a force plate during 6 trials of 45 s (3 EO and 3 EC, randomly ordered): 15 s baseline, 10 s with vibration, and 20 s without vibration. Rest intervals of 3 min were given between trials. The center of pressure (COP) in the anterior-posterior direction was calculated and then normalized by the base of support. 3 variables were defined: (1) mdV: maximal range of COP displacement during vibration, (2) tAB: time between the motor switched off and the achievement of balance values similar to baseline, and (3) MU: movement units occurred during tAB. Mean values for each vision condition were calculated and used to compute 3 (Skill Level) x 2 (Vision) ANOVAs.

RESULTS: ANOVAs' results showed a significant Skill Level x Vision interaction ($F(2,42)=4.065$; $p=.001$; $\eta p^2=.162$) for the mdV variable. Pairwise comparison indicated that: (1) AG standing with EC displaced less their COP than the NG; and (2) AG was the only group that presented no differences between EO and EC conditions during vibration. A significant Skill Level main effect ($F(2,42)=3.529$; $p=.038$; $\eta p^2=.144$) was found for the MU variable showing lower values for the IG than NG. Also, a trend ($p=.061$) for the tAB variable pointed to IG's faster balance adjustment than NG.

CONCLUSIONS: In conclusion, sensory reweighting processes in children showed different characteristics depending on their gymnastics skill level. AG children seemed to be less affected by proprioceptive perturbation with eyes closed. These results could indicate a higher weight of the vestibular system to adjust balance in AG children. On the other hand, IG children showed improved proprioceptive re-integration suggesting they maybe more dependent on their proprioceptive inputs.



O.3.5 Gender affects the development of motor learning ability

Kristin Musselman¹, Erin Vasudevan², Gelsy Torres-Oviedo³, Amy Bastian⁴

¹Toronto Rehabilitation Institute/University of Toronto, ²Stony Brook University, ³University of Pittsburgh, ⁴Johns Hopkins School of Medicine/Kennedy Krieger Institute

BACKGROUND AND AIM: Walking in the real world requires the ability to rapidly learn new gait patterns. For example, when we walk on ice, we quickly change our gait to maintain stability. Motor adaptation is a well-studied type of short-term motor learning that is error-driven and cerebellum-dependent.¹ To study gait adaptation, we use a split-belt treadmill, which has a separate belt for each leg. When the belts move at different speeds, an asymmetric gait results - the step lengths of the two legs are unequal. After several minutes of practice, the gait becomes more symmetrical. Children adapt more slowly than adults², which may reflect the immaturity of their sensorimotor nervous system. The cerebellum shows a protracted development, with total volume not reaching adult values until about 12 years of age in females and 16 years in males.³ Given these gender differences in cerebellar development, girls and boys may differ in their ability to adapt. The aim of our study was to compare gait adaptation between males and females across childhood and adolescence. **METHODS:** Typically-developing children, aged 3-17 years, walked on a split-belt treadmill under 2 conditions: 1) 'tied-belts' for 3 min, and 2) 'split-belts' for 15 min. In 'tied-belts', the belts moved at the same speed, with the speed determined by the child's leg length. In 'split-belts', one belt moved at twice the speed of the other belt. Step length (SL) symmetry was used to measure adaptation, and was calculated for each stride as follows: $(\text{fast SL} - \text{slow SL}) / (\text{fast SL} + \text{slow SL})$. Children were divided into five age groups/gender (3-5, 6-8, 9-11, 12-14 and 15-17 years), for a total of 10 groups. To compare adaptation across groups, mean SL symmetry, binned into groups of 30 consecutive strides, were compared using a 2-way repeated measures ANOVA (gender x age). Significance was set at 0.05. The Bonferroni test was used for post-hoc analyses. **RESULTS:** 164 children participated (85 males, 81 females), with 13-20 children/group. Significant main effects were found for age ($p < 0.001$) and time ($p < 0.001$), as has been shown previously². While the main effect of gender did not quite reach statistical significance ($p = 0.06$), the interaction of time and gender did ($p < 0.001$). Females showed a more rapid return toward symmetry after 100-150 strides. This gender gap was most evident in the 9-11 year olds. By the end of split-belt walking (i.e., last 30 strides), the girls were more symmetrical (i.e., smaller SL symmetry values) than the boys across ages ($p < 0.001$), with the exception of the 6-8 year olds ($p = 0.02$). **CONCLUSIONS:** Gender differences in gait adaptation exist. The differences were most prominent in 9-11 year olds, with females showing a more mature adaptation pattern. This finding aligns with the structural development of the cerebellum, which occurs more rapidly in girls than boys³ ¹Morton & Bastian 2006 J Neurosci ²Vasudevan et al. 2011 J Neurosci ³Tiemeier et al. 2010 Neuroimage



O.3.6 Estimating metabolic cost during non-steady state walking

Jessica Selinger¹, Max Donelan¹

¹Simon Fraser University

BACKGROUND AND AIM: Steady state measurements of metabolic cost have provided valuable insight into why and how we walk the way we do. Measures of oxygen consumption and carbon dioxide production made at the mouth are routinely used to estimate steady state energy use by muscle. However, gas reservoirs, cardiopulmonary control mechanisms and high breath-by-breath variability complicate the instantaneous relationship between muscle energy use and measured metabolic cost. Consequently, metabolic cost is traditionally only assessed during relatively long periods of steady state conditions, thereby constraining the research questions that can be effectively answered. The purpose of this study was to expand on traditional methods of assessing metabolic cost by estimating instantaneous muscle energy use during non-steady state gait. An ability to measure instantaneous energy use may help us understand how we adapt to changing environments, compensate for injury or motor control deficits, and learn new tasks. **METHODS:** To identify the relationship between muscle energy use and metabolic cost during walking, we had subjects complete a series of enforced changes in gait. By rapidly changing treadmill speed (walking speed) and metronome frequency (step frequency) we aimed to evoke a rapid change from one gait pattern to another, and thereby enforce a change in muscle energy use that approximates a step function (Figure 1A). We then used optimization methods to test the ability of different models for capturing the dynamic relationship between our input muscle energy use and output metabolic cost (Figure 1B). To stringently test if our solved model could be used to estimate muscle energy use from the measured metabolic cost response, we enforced different muscle energy use profiles (step, ramp, and exponential decay profile). We then used our model to test two approaches for estimating instantaneous muscle energy use from measured metabolic cost: a forward model and an inverse model approach (Figure 1C and 1D). **RESULTS:** We found that the dynamic relationship between muscle energy use and measured metabolic cost could be modeled using a first order linear ordinary differential equation. Across all subjects, model fits yielded an average exponential time constant of 42 ± 12 s (mean \pm SD). Using our forward and inverse model approaches, we were able to produce estimates of muscle energy use from measured metabolic cost that closely matched the step, ramp, and exponential decay profiles, even during regions that were distinctly non-steady (0.84-0.99 R²). **CONCLUSIONS:** Our results suggest that it is indeed possible to estimate instantaneous muscle energy use from metabolic cost measures during non-steady state gait. Using this technique, it is now possible to explore the role of energetic cost during locomotor adaptation and learning.

O.3.7 Body lateropulsion and visual vertical tilts in unilateral midbrain infarctions: a lesion-behavior mapping and FDG-PET study

Marianne Dieterich¹, Sandra Becker-Bense¹, Peter Bartenstein¹, Bernhard Baier²

¹Ludwig-Maximilians University of Munich, ²University of Mainz and Edith-Stein Clinic, Bad Bergzabern



Background and aim. Previous PET imaging studies disclosed different compensation strategies in acute vestibular lesions depending on the lesion site despite similar clinical syndromes. After peripheral vestibular lesions compensation preferably occurs at cortical level [1,2], whereas after vestibular nucleus lesions (presenting with eye, head and body tilt and lateropulsion) it mainly occurs within brainstem-cerebellar loops [3]. The aim of this combined imaging study in acute unilateral midbrain infarctions was twofold: to determine (i) the vestibular deficit in verticality perception by voxelwise lesion-behavior mapping (VLBM), and (ii) whether - and in which way - the PET pattern differs from that found in patients with medullary brainstem or peripheral vestibular lesions. **Methods.** A detailed neurootological testing was performed and the adjustments of the subjective visual vertical (SVV) were tested in 17 patients with acute unilateral midbrain strokes. On the basis of pathological SVV tilt, patients were divided into two groups for VLBM analysis. Eight patients showed pathological body and SVV tilts, five of them a complete ocular tilt reaction. These eight patients underwent additional resting state FDG-PET with eyes closed twice: (A) in the acute phase, (B) 6 months later after recovery. **Results.** VLBM subtraction analysis in patients with pathological SVV tilts showed lesioned voxels preferentially in rostral paramedian mesencephalic-diencephalic regions: the interstitial nucleus of Cajal (INC) and the rostral interstitial nucleus of the medial longitudinal fasciculus (riMLF). Patients with normal versus pathological SVV tilts revealed lesioned voxels in more lateral mesencephalic regions. The contrast of PET A (acute stage) vs. B (after recovery) gave bilateral signal differences mainly in limbic and inferior temporal cortex areas, partly merging into the inferior-most insular region, but no clusters in the known cortical vestibular network. Comparison of PET A with those of healthy volunteers revealed glucose metabolism increases predominantly in the cerebellum, whereas at cortical level bilateral signal decreases dominated in the thalamus, frontal eye fields, and anterior cingulum. **Conclusion.** Thus, INC/riMLF is an important midbrain relay station of the ascending vestibular pathways to the cortex. Damage to this "gateway" caused a bilateral disconnection of the vestibular cortical network: there were neither visual temporo-parietal activations nor the perception of vertigo. Compensation seems to preferably occur via brainstem-cerebellar loops as well as functional downregulation of thalamo-cortical structures bilaterally. **References.** [1] Bense S., Bartenstein P., Lochmann M., Schlindwein P., Brandt T., Dieterich M.: Metabolic changes in vestibular and visual cortices in acute vestibular neuritis. *Ann Neurol* 2004;56: 624-630. [2] Becker-Bense S, Dieterich M, Buchholz H-G, Bartenstein P, Schreckenberger P, Brandt T: The different

O.3.8 Effects of Levodopa on Adaptation of Reactive Stepping in People with Parkinson's Disease

Daniel Peterson¹, Bauke Dijkstra¹, Fay Horak¹

¹Oregon Health & Science University

Background and aim: Compensatory steps in response to postural perturbation (e.g. a slip) are critical to avoid falls and are impaired in people with Parkinson's disease (PD) (King et al. 2010). Practicing compensatory stepping may lead to improved stepping; however, given the importance of dopamine for motor learning (Graybiel 2005), people with PD may have an altered ability to improve reactive stepping. Further, levodopa, a commonly prescribed dopamine replacement drug, may affect how people learn. The degree to which dopamine replacement therapy with levodopa affects the ability to



learn stepping responses is unknown. Thus the aim of this study is to determine how levodopa effects adaptation, retention, and transfer of learning for reactive stepping in people with PD. Methods: Twelve people with PD completed 4 visits. Visit 1: Participants underwent 25 anterior and 25 posterior (A/P) randomly-ordered support surface translations (i.e. postural perturbations; 55cm/s) that elicited compensatory steps. Ten medio-lateral (ML) perturbations were also delivered. Visit 2: 24 hours later, participants completed 10 AP and 10 ML perturbations to assess retention and generalization of adaptation, respectively. Visits 3&4: Each subject returned to the lab 6-8 weeks later and repeated the protocol. One set of visits were ON dopaminergic medication, and one set was OFF (12 hour withdrawal). Order of testing was randomized. The primary outcome was peak displacement of the center of mass (COM) after the perturbations. Secondary outcomes included number of steps, step length (SL), and step time (ST). Analyses focused on backward stepping as this direction is particularly challenging for people with PD (Horak et al. 2005). Results: Over the 50 perturbations, PD improved stepping responses (COM: $F_{4,36}=3.1$; $p=0.025$; Number of steps: $F_{4,36}=3.8$; $p=0.009$). Time x medication effect was not significant ($F_{4,36}=0.85$; $p=0.49$), suggesting dopaminergic medication did not significantly alter stepping adaptation. Improvements in COM movement and number of steps were retained over 24 hours ($F_{1,9}=5.0$; $p=0.045$ & $F_{1,9}=6.1$; $p=0.031$, respectively). Improvement of AP stepping did not transfer to ML stepping, as COM displacement in response to ML perturbations was not significantly altered by medication status ($F_{1,11}=1.6$, $p=0.23$). Conclusions: Individuals with PD improved stepping responses with practice and retained these improvements over 24 hours both with and without dopamine replacement therapy. Although levodopa may be effective at improving voluntary movements (e.g. reaching and stepping) in PD, it seems to be less important for learning to improve compensatory stepping. These results are contrary to previous findings that levodopa causes subtle decrements in implicit (Semrau et al. 2014) and explicit (Kwak et al. 2010) motor learning in people with PD. Additional testing is necessary to elucidate ways to improve generalization of learned stepping responses.

O.4.1 Does a startling acoustic stimulus accelerate postural responses to balance perturbations in stroke survivors?

Milou Coppens¹, Jolanda Roelofs¹, Nicole Donkers¹, Jorik Nonnekes¹, Alexander Geurts¹, Vivian Weerdesteyn¹

¹Radboudumc

BACKGROUND AND AIM: Rapid postural responses are essential to recover from balance perturbations and prevent falling¹. After stroke, responses to external perturbations are delayed². A startling acoustic stimulus (SAS) can accelerate reaction times of planned movements (StartReact), presumably by neural pathways other than the corticospinal tract³. As this tract is unilaterally damaged after stroke, our aim was to study the StartReact effect in isolated ankle dorsiflexion movements and in postural responses after stroke. **METHODS:** Fifteen people with chronic stroke and 15 healthy age-matched controls will be included in this study. As yet, data were analyzed from five stroke survivors and six healthy controls. Subjects performed ankle dorsiflexion as fast as possible on a visual imperative stimulus, together with a SAS (120 dB) in 25% of 16 trials with each leg. Thereafter, subjects received 16 backward balance



perturbations induced by forward support surface translation (0.5 m/s^2), together with a SAS in 25% of the trials. Subjects performed a feet-in-place response to recover balance. For both tasks, we determined onsets of the tibialis anterior (TA) to study differences between SAS and non-SAS trials and the paretic and non-paretic leg. Furthermore, maximal body excursion (displacement of C7 marker) was analyzed following perturbations. Due to the preliminary nature of the data, statistics are not yet applied. At the time of the conference, data of all participants will be available and final results will be presented. RESULTS: All stroke survivors were able to perform ankle dorsiflexion movements. Onset of TA was earlier in SAS trials versus non-SAS trials in the non-paretic leg (109 ± 15.8 vs. 148 ± 24.7 ms) and even more in the paretic leg (113 ± 46.4 vs. 164 ± 17.8 ms). Except for non-SAS trials in the paretic leg, reaction times were similar to those in healthy controls (dominant leg: 111 ± 26.2 vs. 152 ± 18.2 ms; non-dominant: 111 ± 14.8 vs. 149 ± 10.6 ms). Responses in TA after balance perturbations were facilitated by a SAS in the non-paretic leg (116 ± 29.2 vs. 153 ± 13.9 ms) and in the paretic leg (128 ± 39.6 vs. 179 ± 28.8 ms). A SAS also resulted in a smaller body excursion (57 ± 19.3 vs. 66 ± 19.1 mm). CONCLUSIONS: In a simple reaction time task, the StartReact effect normalized TA response onsets in stroke survivors in the paretic leg. Similar results have been shown in another patient group (HSP) with corticospinal damage³ and are suggestive of potent reticulospinal drive to distal leg muscles. Also, responses to balance perturbations were facilitated by a SAS, resulting in smaller body excursions. Although TA facilitation by the SAS was observed in the paretic leg, onset latencies seemed to lag those in the non-paretic leg. This finding, however, needs further confirmation. References: 1Maki & McIlroy. Age Ageing, 2006;35(Suppl 2):ii12-ii18 2Weerdesteyn et al. J Rehabil Res Dev, 2008;45(8):1195-1214 3Nonnekes et al. J Neurosci, 2014;34(1):275-81

O.4.2 ARE DELAYED POSTURAL RESPONSES TO PERTURBATIONS ASSOCIATED WITH POORER BALANCE CAPACITY IN PEOPLE AFTER STROKE?

Digna de Kam¹, Amber Bruijnes¹, Jolanda Roelofs¹, Alexander Geurts¹, Vivian Weerdesteyn¹

¹Radboud University Medical Center

OBJECTIVE: Postural instability is a major risk factor for falls in people after stroke. Postural responses to balance perturbations are delayed and reduced in these patients. We aimed to identify whether delayed and reduced responses are associated with poorer balance capacity in people after stroke. METHODS: Twenty five people after a unilateral stroke (>6 months) and 14 controls were subjected to translational balance perturbations in four directions in random order. Using an iterative protocol, we identified the highest perturbation intensity that could be recovered 1) without stepping (stepping threshold), and 2) with a maximum of one step (limit of stability). The protocol also included additional perturbations at intensities of 0.5 m/s^2 and 1.5 m/s^2 ($n=4$ for each direction and intensity) to allow between-subjects comparisons of EMG variables. We determined the onset latencies and response amplitudes of tibialis anterior and rectus femoris for backward perturbations; gastrocnemius, soleus and biceps femoris for forward perturbations; and the gluteus medius and peroneus on the perturbed side for lateral perturbations. We compared EMG outcomes, stepping thresholds and limits of stability between patients and controls. To identify possible associations between EMG variables of the affected leg and reduced stepping thresholds and limits of stability, we used a linear regression (enter method). RESULTS:



Irrespective of perturbation direction, people with stroke had lower limits of stability than controls ($p < 0.05$). Stepping thresholds in patients were lower only in the forward direction ($p = 0.01$). EMG onset latencies on the affected side were delayed for all muscles except the biceps femoris and soleus ($p < 0.05$), whereas these were similar to controls on the unaffected side. Response amplitudes on the affected side were lower in all muscles, except the soleus and peroneus ($p < 0.05$). In people after stroke, EMG variables explained 43.6 and 14.6% of the stepping threshold in the forward direction and towards the affected side respectively. EMG variables accounted for 68.6% of the variance of the limits of stability towards the affected side. Significant predictors were onset and amplitude of the gluteus medius and onset of the peroneus. EMG variables explained 45.6% of the forward (gastrocnemius onset and amplitude) and 35.4% of the backward limits of stability (rectus femoris amplitude). **CONCLUSIONS:** The ability to sustain postural perturbations is impaired after stroke. Postural responses are delayed and reduced on the affected side. The resulting detrimental effects for sustaining balance perturbations were particularly evident towards the affected side, with the hip abductors playing a crucial role. The delayed and reduced activation of these muscles presumably hampers quick unloading of the affected leg for side stepping to recover balance, which may underlie the propensity to fall towards the affected side in people after stroke.

O.4.3 Altered functional connectivity correlates with motor and cognitive control measures within clinical subtypes of Parkinson's disease

Griet Vervoort¹, Aniek Bengevoord¹, Wim Vandenberghe¹, Alice Nieuwboer¹

¹*KU Leuven*

Background and aim: Patients with Parkinson's disease (PD) are known to have altered cortico-cortical and frontostriatal functional connectivity (FC). It is currently unclear if PD subtypes show distinct FC patterns and how this relates to motor and cognitive control. Therefore, we compared FC between patients with the postural instability and gait disorder (PIGD) and tremor dominant (TD) subtype using resting state functional MRI (rs-fMRI) and correlated this with behavioral measures. Methods: 59 PD patients and 18 healthy age-matched healthy controls were included. PD Patients were classified as PIGD ($n=33$), TD ($n=18$) or indeterminate ($n=8$) based on OFF MDS-UPDRS subscores. Indeterminate patients were excluded from further analyses. Patient subgroups were matched for age and disease severity. All subjects underwent an OFF rs-fMRI scan using a Philips 3T MRI scanner (FEEPI sequence, duration: 435s, TR: 1.7ms) combined with a high-resolution anatomical T1 sequence. Temporal and spatial preprocessing was done using SPM8. The CONN toolbox was used to compute FC of selected cortical and subcortical regions of interest (ROIs) related to motor and cognitive control. Group differences in ROI-to-ROI FC were explored using FDR-corrected t-tests ($p < 0.05$). Behavioral parameters discriminating between PD subgroups were identified in an earlier study: i.e. PIGD and TD scores, Mini Mental State Examination (MMSE), Mini-BESTest, step length, coordination during a bimanual upper limb (UL) task and amplitude during a bilateral lower limb (LL) task. Pearson or Spearman correlations were calculated between ROIs with altered between-group FC and behavioral measures. Results: In PIGD, the dorsolateral prefrontal cortex (DLPFC) had increased FC with the posterior cingulate cortex (PCC) and putamen compared to TD. In addition, the medial prefrontal cortex showed increased FC with



the premotor cortex (PMC) and decreased FC with the pedunculo-pontine nucleus (PPN) in PIGD compared to TD. When compared to controls, PIGD showed additionally decreased FC within the PCC and putamen. On the other hand, TD showed decreased FC within the putamen and increased FC between the PPN and thalamus compared to controls. There was a trend for increased FC between the PPN and the PMC and primary motor cortex (M1) in TD. FC between the DLPFC and the PCC and putamen positively correlated with the PIGD score and UL coordination while FC between the DLPFC and PCC correlated negatively with the TD and MMSE scores. LL amplitude correlated positively with the FC between putamen and M1. Conclusion: These results indicate distinct changes in neural connectivity associated with clinical PD subtypes. Decreased FC in frontostriatal/PPN network may explain the greater gait, balance and cognitive deficits in PIGD while increased cortico-cortical FC suggests a compensatory strategy. Increased FC between M1/thalamus and PPN in TD may indicate compensatory activity which is not present in PIGD.

O.4.4 Perturbation-based balance training improves step quality in people with chronic stroke

Jolanda Roelofs¹, Hanneke van Duijnhoven¹, Jasper den Boer¹, Geert van Bon¹, Alexander Geurts¹, Vivian Weerdesteyn¹

¹Radboud University Medical Centre

BACKGROUND AND AIM: Taking a step to recover balance is an important strategy to prevent falling. In people after stroke the quality of these steps is often impaired, which increases their risk of falling¹. The aim of this study was to identify whether a 5-week perturbation-based balance training would improve step quality in people with chronic stroke. **METHODS:** Twenty people with chronic stroke (Functional Ambulation Categories score 4-5) were randomly assigned to an intervention group (n=10) or to a waiting list control group (n=10). The intervention consisted of a 5-week perturbation-based balance training (10 sessions of 45 minutes per session) on a movable platform. Support-surface translations that induced stepping responses were delivered in eight different directions at increasing intensity and unpredictability. Balance assessments for both groups took place pre intervention, post intervention and six weeks after intervention (retention). In addition, the control group had a baseline assessment six weeks before the intervention (Fig 1). Each assessment consisted of five backward (bwLaR) and five forward (fwLaR) lean and release trials at inclination angles of 8.6 ± 2.9 and $11.8 \pm 3.2^\circ$, respectively. The leg angle at foot contact was our primary outcome measure, as this is a strong indicator of step quality². We compared leg angles between pre intervention, post intervention and retention assessments (repeated measures ANOVA) for the study population at large. For the control group, we also compared leg angles between baseline and pre intervention. **RESULTS:** A main effect of time was found for both bwLaR ($p=0.013$) and fwLaR ($p<0.01$). For bwLaR, the leg angle at pre intervention was $1.6 \pm 3.9^\circ$. Larger leg angles post intervention ($\Delta=4.0 \pm 5.0^\circ$, $p=0.019$) were retained after six weeks ($\Delta=0.03 \pm 5.2^\circ$, $p=0.98$). FwLaR trials yielded the same pattern of results with initial angles of $22.3 \pm 3.4^\circ$, which were increased post intervention ($\Delta=3.0 \pm 3.2^\circ$, $p=0.003$) and retained six weeks later ($\Delta=0.03 \pm 2.1^\circ$, $p=0.96$). Improvements following training were similar between groups (group x time, $p>0.41$). For the control group, leg angles were not different between baseline and pre intervention, which demonstrates the absence of learning effects on the task at hand (bwLaR: $\Delta=0.75 \pm 4.0^\circ$, $p=0.67$; fwLaR: $\Delta=-0.13 \pm 4.4^\circ$,



p=0.94). No adverse events of training occurred. CONCLUSIONS: The 5-week perturbation-based balance training was effective in improving step quality in people with chronic stroke, as indicated by the larger leg angles post intervention. Importantly, improvements were retained after six weeks. These findings are not only promising for people after stroke, but also for other populations with balance impairments. Further research is needed to establish whether an improved step quality indeed translates to fewer falls in daily life. REFERENCES: ¹Mansfield et al. *Neurorehabil Neural Repair*, 2013;27(6):526-33
²Weerdesteyn et al. *Gait Posture*, 2012;35(3):462-6

O.4.5 Effects of training with a new Smartphone-based biofeedback system (CuPiD) on mobility in people with Parkinson's disease: Clinical outcomes

Pieter Ginis¹, Moran Dorfman², Eran Gazit², Alberto Ferrari³, Laura Rocchi³, Lorenzo Chiari³, Jeffrey Hausdorff², Anat Mirelman², Alice Nieuwboer¹

¹KU Leuven, ²Tel Aviv Sourasky Medical Center, ³University of Bologna

BACKGROUND AND AIM: Lightweight inertial sensors embedded in smartphone technology make it possible to provide accurate feedback of motor performance in real-time. The present randomized study assessed the effectiveness of a newly developed home-based application (CuPiD) for people with Parkinson's disease (PD), providing feedback to enhance gait training in comparison to clinical advice only. **METHODS:** In a phase II study, 39 persons with PD were randomized to the CuPiD intervention or a control group (CTR). In both arms, PD persons were encouraged to walk 3x/week for 30 min. over a period of 6 weeks. Gait advice was provided by a therapist during a weekly home visit in both arms. CuPiD participants were additionally equipped with the CuPiD-system. CuPiD delivered intelligent verbal feedback in real-time via headphones and a smartphone integrating data from 2 shoe-worn inertial sensors (EXLs3). Feedback was triggered when a person's gait pattern deviated from a pre-recorded optimal reference walk. Pre- and posttests were conducted in the lab, and after a 4 week follow-up. The primary outcome was 1 min. gait speed under single (ST) and dual task (DT) conditions measured with GAITRite. Other tests included the 2 min. walk test, MiniBEST-test, Short Physical Performance Battery, and questionnaires to assess disease severity, gait confidence, freezing of gait and quality of life (QoL). Repeated measures ANOVA was used to assess interaction (group*time) and main (group or time) effects with a Bonferroni corrected post-hoc analysis. **RESULTS:** CuPiD and CTR groups were well-matched for age, disease duration, cognition and disease severity (p>0.33). Both groups showed high training adherence (CuPiD: 682.4 [261.7] min; CTR: 624.8 [345.3] min; p=0.58) and walked above the encouraged total of 540 min. The CuPiD system was well-used and tolerated by patients. ST and DT gait speed showed a main effect of time (p<0.01) but no significant group by time effect, indicating that both groups improved similarly. However, when expressed as a percentage of baseline, ST gait speed improved in CuPiD with 9.3% [11.0] post-training and persisted at retention (10.9% [10.1]). In contrast, CTRs improved by 5.4% [11.4] post-training and 7.0% [11.5] at follow up. In addition, DT gait speed improved in CUPIID with 13.5% [19.2] and at follow up with 11.9% [13.3], while CTRs improved with 6.6% [12.6] and 8.4% [16.6] at follow up. Other gait and balance tests showed no significant improvement after training and also disease characteristics and QoL measurements remained constant over the study period. **CONCLUSION:** The CuPiD-system improved gait speed at least to the same degree as clinical



advice. However, effects sizes expressed as a percentage of baseline were larger in the CuPiD group, suggesting that the CuPiD approach may have advantages and that the current study may have been underpowered. Overall, CuPiD offers a promising self-management tool for effective gait training in PD.

O.4.6 Postural Control Alterations in Healthy LRRK2 G2019S Mutation Carriers

Yoav Beck¹, Kathrin Brockmann², Bjørg Warø³, Claustre Pont Sunyer⁴, Susan Bressman⁵, Karen Marder⁶, Nir Giladi¹, Jeffrey Hausdorff¹, Anat Mirelman¹

¹Tel Aviv Sourasky Medical Center, ²University of Tübingen, ³Norwegian University of Science and Technology, ⁴Universitat de Barcelona, ⁵Mount Sinai-Beth Israel Medical Center, ⁶Columbia University

BACKGROUND AND AIM: Increasing effort focuses on the identification of early markers of Parkinson's disease (PD). Indeed, there is compelling evidence supporting the possibility that subtle motor changes can be detected in the prodromal phase. Studies in healthy adults have shown that gait variability in LRRK2 G2019S mutation carriers was worse than in non-carriers and balance deficits were identified in individuals with a high risk for developing PD during challenging conditions. The present work extends these earlier studies to investigate, for the first time, sway in healthy asymptomatic LRRK2 G2019S mutation carriers, a group of adults with an increased risk of developing PD. **METHODS:** The study was conducted as part of the 'gait Consortium LRRK2 study' funded by the Michael J Fox foundation which included groups from Israel, USA, Germany, Norway and Spain. Sway measurements were collected using a 3D accelerometer worn on the lower back. Sixty-one non-manifesting LRRK2 G2019S mutation carriers (NMC) and 61 non-manifesting non-carriers (NMNC) participated in the study. Subjects were asked to stand quietly for 30 seconds in a comfortable base of support and eyes open. Sixty-four different parameters were calculated from the accelerometer signals: 22 in the time domain, 10 in the frequency domain, and 32 in phase space. **RESULTS:** The groups were similar with respect to age, gender, height, weight, and cognitive function, as measured using the Montreal Cognitive Assessment ($p > 0.3$). In order to account for multiple comparisons a threshold of $0.05/64 = 0.0008$ was used for significance. Differences between groups were observed in the time domain. Mean velocity of the COM in the medio-lateral (ML) direction (NMC: 0.01 ± 0.008 m/sec, NMNC: 0.026 ± 0.019 m/sec, $p < 0.0001$) and path length in the anterior-posterior (AP) direction were higher in the non-carriers. (NMC: 28.52 ± 0.726 m/sec², NMNC: 29.37 ± 1.134 m/sec², $p = 0.0002$). A significant difference between groups was also observed in phase space analysis, which is the mean length of the diagonal lines in the recurrence plot in the AP direction. This measure, which reflects the average length of a recurring state was larger in the carriers (NMC: 5.519 ± 1.291 , NMNC: 4.628 ± 0.697 , $p = 0.0003$). **CONCLUSIONS:** These results support the existence of subtle motor changes in postural control among healthy G2019S mutation carriers. Time, frequency and phase space measures demonstrate more constrained movements among carriers which reflect decreased sway. While these initial findings are quite promising, larger scale longitudinal studies are needed to further investigate sway kinematics as a predictor of the disease and as a marker for disease progression.



O.4.7 Gait is a sensitive marker of motor progression in early Parkinson's disease: A longitudinal correlational analysis

Brook Galna¹, Sue Lord¹, Lynn Rochester¹

¹Newcastle University

BACKGROUND AND AIM: Sensitive markers to track motor progression in Parkinson's disease (PD) are required for measuring change in response to novel and disease modifying therapies. However, it is unclear which of the many gait characteristics are most sensitive to disease progression and whether it is only a useful marker in people with a Postural Instability and Gait Difficulty (PIGD) dominant phenotype. The aims of this analysis were to identify: i) which gait characteristics correlate most strongly with disease severity using a longitudinal correlational analysis; and ii) whether the strength of these correlations differ in people with PIGD and tremor dominant PD. **METHODS:** Disease severity (Unified PD rating scale - movement assessment: UPDRS III) and gait were assessed in 108 people with incident PD (68±10 years, 36 females, UPDRS III: 25±10, <4 months post diagnosis, Phenotype: PIGD n=50, Tremor n=47, Indeterminate n=11) and again 18 months later. Gait was measured for two minutes (preferred pace) using an instrumented walkway (GAITRite). Sixteen gait variables were calculated, the selection of which was based on a validated model of gait [1]. Pearson correlations were used to explore the relationship between decline in gait and decline in the UPDRS III over 18 months for the whole group, and in PIGD and tremor subgroups. Forward stepwise linear regression was used to identify which gait characteristics or combination thereof explained most change in the UPDRS III. **RESULTS:** Longitudinal correlations showed that an increase in the UPDRS III (more severe symptoms) was most strongly correlated with a decline in step velocity ($r = -.356$), step length ($r = -.291$), step time ($r = .272$) and stance time ($r = .346$) ($p < .01$), with weaker but significant correlations found for temporal (step, swing and stance time) asymmetry ($p < .05$). Stepwise linear regression revealed that decline in step velocity was the strongest independent explanatory factor of change in the UPDRS III and was the only variable held in the final model ($r^2: 12.7\%$, $F: 15.4$, $p < .001$), with a decline of 2.8cm/s reduction in step velocity corresponding to an increase of one point on the UPDRS III. Secondary analysis showed stronger correlations between gait and disease severity in the PIGD subgroup although no significant correlations were found in the tremor dominant subgroup. **DISCUSSION:** Gait is a sensitive marker of early PD motor progression in people with a PIGD phenotype, with step velocity being identified as the most sensitive characteristic. However, gait does not track motor progression in people with tremor dominant disease. Our findings suggest that gait may be a useful tool to measure change in response to novel and disease modifying therapies, and highlights the need for more selective recruitment as well as choice of outcomes based on motor phenotype. **REFERENCES:** [1] Lord S et al. J Gerontol A Biol Sci Med Sci, 2013; 68(7):820-827.

O.4.8 Measuring and minimizing walking-induced fatigue in people with Multiple Sclerosis.

James McLoughlin¹, Christopher Barr¹, Maria Crotty¹, Ben Patrilli², Daina Sturnieks³, Steven Lord³

¹Flinders University, ²Repatriation General Hospital, ³Neuroscience Research Australia, University New South Wales



BACKGROUND AND AIM: Fatigue and difficulty with mobility are major problems for people with Multiple Sclerosis (MS). The aim of our research was to investigate the effects of walking induced fatigue on a number of key mobility related motor impairments, and test a targeted intervention designed to minimize these effects. **METHODS:** Thirty-four people with moderately disabling MS participated in 3 assessment sessions. Each session involved one of three 6-minute conditions: (1) seated rest, (2) 6 minute walk test (6MWT) and (3) 6MWT with a Dorsiflexion Assist Orthosis (DAO). Standing postural sway, lower limb strength, simple and choice reaction time and gait were all comprehensively assessed before and after each 6-minute condition. A matched sample of 10 healthy controls also completed the 6MWT protocol. **RESULTS:** The 6MWT resulted in a significant increase in perceived fatigue ($p < 0.01$), postural sway with eyes open ($p < 0.05$), eyes closed ($p < 0.01$), simple and choice reaction time (all $p < 0.01$), and reductions in knee extensor ($p < 0.05$) and ankle dorsiflexor ($p < 0.01$) strength. There were no changes in healthy control subjects. A number of gait variables that changed following fatigue included increases in joint moments, powers in stance phase and reduced ankle dorsiflexion at initial contact (all $p < 0.01$). The use of the DAO was effective in reducing the physiological cost of walking ($p < 0.01$) and mitigating the fatigue effects on knee extensor strength ($p < 0.05$) and eyes open standing postural sway ($p < 0.01$). **CONCLUSIONS:** We have identified a number of fatigue related motor impairments impacting safe mobility in people with moderately disabling MS. Targeted interventions, such as the DAO, that aim to minimize these fatigue related effects may lead to more effective rehabilitation therapy in this population.

O.5.1 Prioritization during dual tasking on a circular path is different from prioritization on a straight walking path in older people with poor cognitive flexibility

Markus Hobert¹, Carolin Bellut¹, Sandra Hasmann¹, Jana Staebler¹, Gerhard Eschweiler¹, Daniela Berg¹, Walter Maetzler¹

¹University of Tuebingen

BACKGROUND AND AIM In older people, cognitive flexibility influences gait, especially in dual task situations. In lab-based studies, this has usually been investigated on straight walking paths. In daily life of older adults, proper performance of curved walks and turning is potentially more relevant than straight walking performance, as falls occur more often during turning. As we hypothesized that turning movements require higher levels of cognitive flexibility, this study aimed at comparing dual task costs (DTC) in older people with good and poor cognitive flexibility as they occur on a straight walking path, with DTC during walking on a circular path. **METHODS** In the frame of the TREND-study, 1054 participants (median age 64 years) were categorized into groups according to their cognitive flexibility as measured with the Trail Making Test (TMT). Delta TMT (part B minus part A) was used to classify good, intermediate and poor TMT performers. Good TMT performers ($< 34s$) were then compared to poor TMT performers ($> 55s$). All participants performed walks under single and dual task conditions (subtracting serial 7s as fast as possible) on a straight 20m walking path, and on a circular (diameter 1.2m) walking path. Dual task costs (DTC) were calculated to estimate prioritization of tasks. **RESULTS** During straight walking, DTC of subtracting speed (3.9% in good TMT performers, -1.0% in poor TMT performers, $p = 0.02$) were significantly different between the cohorts, but not the DTC of walking speed (14.2% in



good TMT performers, 17.2% in poor TMT performers, $p=0.10$). During circular walking, these effects were exactly the opposite: DTC of walking speed (17.5% in good TMT performers, 25.5% in poor TMT performers, $p<0.0001$) were significantly different between the cohorts, but not DTC of subtracting speed (5.0% in good TMT performers, 1.0% in poor TMT performers, $p=0.10$). CONCLUSIONS Patterns of DTC indicate that poor TMT performers have a "walking second" strategy during both straight and circular walking, potentially increasing their risk for gait disturbances and falls. Moreover, our experiment indicates that older persons with limited cognitive flexibility prioritize the cognitive task over the walking task in particular when the walking situation is difficult. If confirmed in future studies, this surprising result may have implications for fall prevention strategies in the elderly.

O.5.2 A virtual reality avatar interaction (VRai) platform for context specific return to function assessment: an example of complex locomotor navigation for the military

Bradford McFadyen¹, Philip Jackson¹, Luc Hébert¹, Catherine Mercier¹, Nicolas Robitaille¹, Laurent Bouyer¹, Carol Richards¹, Shirley Fecteau¹

¹Laval University

Introduction: It is still difficult to properly assess continuing sequelae following mild traumatic brain injury (mTBI). Ecologically-based multitasking during locomotor tasks, with their natural demands on planning and equilibrium control, appear to be more sensitive to revealing residual deficits than traditional tests isolating functions. Context is specifically important for return to function assessments, and virtual reality (VR) allows the flexibility to assess such context specificity. The aim of this work is to provide a first proof of the ability of a VR platform using first and third person avatar interactions (VRai) to provide context specificity in order to distinguish performance between soldiers with and without mTBI. Methods: Twelve Canadian soldiers (6 controls and 6 with a history of mTBI; respectively 30.3 years old on average) have been tested with the VRai platform consisting of 3D motion capture (Vicon), virtual environment (VE) rendering (Softimage/Blender) and projection within a head mounted display (Sensics) using commercial software (Vizard). Participants were immersed within a patrolling task (context specificity) through the eyes of a first person avatar reproducing their real time locomotion in order to navigate through a virtual village with different physical and cognitive challenges. Physical complexity of the patrolling task was graded from walking unobstructed to interacting with static and moving third person avatars (TPAs). Multitasking complexity was further augmented by requiring participants to respond to persons presented in building windows with 10 or 20% previously declared as hostile or non-hostile (divided attention and working memory task). Subjects were instructed to maintain their normal patrolling walking speed and respond as quickly as possible to stimuli using a two-way switch mounted on a simulated C7A2 rifle (up for hostile, down for non-hostile). Presence and cybersickness were measured, along with errors for the cognitive task, gait speed and fluidity and obstacle clearance. Results: Moderate to strong presence scores were found for both groups (Cntl=5/7 mTBI=6/7) and all reported high scores on enjoyment of the experience. Simulator sickness was low for both groups (Cntl=0.29/3 TBI=0.55/3). While there were no difference in errors, the control group tended to walk slower and was less fluid for 2 hostiles ($p=0.046$; effect size=0.342) with a tendency for 4 hostiles ($p=0.051$; effect size=0.33) suggesting more focus on the required tasks than the mTBI



group who showed little change in fluidity across conditions. There was no difference in obstacle clearance between groups. Conclusions: The present VR platform provided an effective context specific means (here for the military) to immerse participants and appears to be able to distinguish subtle residual deficits in persons having had an mTBI. The VRai platform potentially offers the flexibility to adapt to different contexts and populations.

O.5.3 Anxiety affects stance and locomotion in acrophobia and phobic postural vertigo

Thomas Brandt¹, Guenther Kugler¹, Roman Schniepp¹, Max Wuehr¹, Doreen Huppert¹

¹German Center for Vertigo and Balance Disorders

Background and aim. Investigation of visual exploration, stance, and gait in acrophobia. Methods. Measurements of eye- and head-movements, postural sway, and gait analysis in susceptibles to acrophobia. Results. Persons with visual height intolerance or acrophobia exhibit typical restrictions of visual exploration and imbalance during stance and locomotion when exposed to heights. Eye and head movements are reduced, and gaze freezes to the horizon. Eye movements tend to be horizontal saccades during stance and vertical saccades during locomotion. Body posture is characterized by a stiffening of the musculoskeletal system with increased open-loop diffusion activity of body sway, a lowered sensory feedback threshold for closed-loop balance control and increased co-contraction of antigravity leg and neck muscles. Walking is slow and cautious, broad-based, consisting of small, flat-footed steps with less dynamic vertical oscillation of the body and head. Conclusions. Anxiety appears to be the critical symptom that causes the typical but not specific eye and body motor behavior, which can be described as tonic immobility. Patients with phobic postural vertigo make very similar alterations in gait control. Ref. Brandt T., Kugler G., Schniepp R., Wuehr M., Huppert D. Acrophobia impairs visual exploration and balance during standing and walking. Ann NY Acad Sci (2015, in press).

O.5.4 Balance impairment and its relation to cognition in a diverse population of elderly fallers and non-fallers

Kim Dockx¹, Esther Bekkers¹, Sabine Verschueren¹, Anat Mirelman², Jeffrey Hausdorff², Alice Nieuwboer¹

¹KULeuven, ²TASMC

Background and aim: Recent studies suggest that elderly with mild cognitive impairment (MCI) have an increased fall risk. However, the interaction between balance performance and cognitive status is not clearly understood. We performed a cross-sectional study to explore the relationship between balance impairment and cognition in a diverse group of elderly. Methods: 17 Fallers with MCI, 29 healthy elderly fallers (EF) and 9 healthy elderly non-fallers (HE) were included in this study. The Mini-Balance Evaluation Systems Test (Mini-BESTest) was used to assess balance control. General cognitive function was measured using the Mini Mental State Examination (MMSE) and the Montreal Cognitive



Assessment (MoCA). The Trail Making Tests A & B (TMT A & B) evaluated specific executive functions. The Physical Activity Scale for the Elderly (PASE) and the Short Form (SF-36) Health Survey measured physical activity and health status. Kruskal-Wallis ANOVA analyzed differences between groups. Spearman Rank Correlation and multiple linear regression analysis explored the relationship between balance impairment and cognition. Results: No differences were found between MCI, EF and HE regarding patient demographics. MCI patients scored significantly worse on all cognitive tests compared to EF (MoCA: $p=0.003$; MMSE: $p=0.008$; TMT A: $p=0.009$; TMT B: $p=0.002$) and HE (MoCA: $p=0.012$; MMSE: $p=0.018$; TMT A: $p=0.001$; TMT B: $p=0.06$). More importantly, even though there was no significant difference between groups regarding physical activity, MCI patients scored worse on SF-36 and Mini-BESTest compared to EF (SF-36: $p=0.026$; Mini-BESTest: $p=0.019$) and HE (SF-36: $p=0.004$; Mini-BESTest: $p=0.000$). A significant correlation was found between the Mini-BESTest and different cognitive scales in the full cohort ($N=55$): MoCA ($R=0.529$; $p<0.001$), MMSE ($R=0.5796$; $p<0.001$) and TMT A ($R=-0.556$; $p<0.001$). In EF, balance was mainly correlated with tests of executive function (MoCA: $R=0.41$; $p=0.03$; TMT A: $R=-0.48$; $p=0.008$; MMSE: $R=0.41$; $p=0.03$), whereas in MCI balance was correlated to the MMSE ($R=0.74$; $p=0.000$). Overall, the MMSE proved to be the strongest predictor of balance impairment, with 32.7% of the variance in Mini-BESTest explained. When using backward stepwise regression, results showed independent contributions of the MMSE ($\beta=0.404$; CI: 0.189-0.618), PASE ($\beta=0.296$; CI: 0.090-0.502) and SF-36 ($\beta=0.298$; CI: 0.090-0.506), explaining 48% of the variance. Conclusions: Despite similar fall rates, MCI fallers have greater balance impairment than EF. Balance performance was most strongly predicted by MMSE scores and less by measures of executive function in MCI and EF respectively. Although the Mini-BESTest scores of this cohort were partially determined by cognitive function, physical activity and health status, 52% of the variance remained unexplained. Future work should explore different cognitive domains and physical components (e.g. gait) as a way to understand the remaining variance.

0.5.5 Are attentional demands of walking affected by variations in lateral balance? A comparison of young and older adults

Masood Mazaheri¹, Melvyn Roerdink¹, Jacques Duysens², Peter Beek¹, Lieke Peper¹

¹MOVE Research Institute Amsterdam / VU University Amsterdam, ²KU-Leuven

BACKGROUND AND AIM: Increased attentional demands of normal walking in older adults have been tentatively attributed to altered visuomotor and/or balance control of walking associated with ageing. In this experiment the attentional costs were assessed in relation to balance control requirements in the frontal plane, for both young and older adults. Balance demands were manipulated by means of two levels of prescribed step width (SW: preferred vs. smaller than preferred) and by means of a lateral external stabilization frame (involving two levels of mechanical stabilization). In this manner, lateral balance was either reduced (small SW) or increased (stabilization frame). It was hypothesized that the attentional demands of walking were higher in situations with lower stability, and that this effect would be more pronounced in older than younger adults. **METHODS:** Twenty young (23.2 ± 3.3 yrs; $M\pm SD$) and twenty older adults (72.9 ± 4.6 yrs) walked on a treadmill at their preferred gait speed while performing a secondary probe reaction time (RT) task. Five walking conditions were tested: (i) unconstrained normal



walking; walking on visual lines projected on the treadmill belt prescribing either (ii) preferred or (iii) narrow SW; and walking within an external stabilization frame attached to the pelvis, involving either (iv) high stiffness (HS) or (v) low stiffness (LS) springs. Each condition was tested twice. Trial duration was 2.5 minutes, during which 21 RT stimuli were presented with the first stimulus serving as warning signal. The median RT values were analyzed using two separate mixed-model ANOVAs: either 2 (group: young vs. older) \times 3 (task: preferred SW vs. small SW vs. normal walking) or 2 (group) \times 3 (task: HS vs. LS vs. normal walking). RESULTS: RT was significantly larger for older compared to young adults. For the SW manipulation, both conditions resulted in significantly larger RT than normal walking but there was no difference in RT between the two prescribed SW conditions. For walking within the stabilization frame, no significant differences in RT were evident between HS and LS conditions, nor between these conditions and normal walking. The group \times task interaction was not significant. CONCLUSIONS: The results indicate that neither decreased (small SW) nor increased lateral stability (stabilization frame) affected the attentional demands of walking. Interestingly, however, RTs were significantly higher when step width had to be attuned to visual lines projected on the treadmill belt. In particular, the obtained difference between normal walking and walking on visual lines at the individual's preferred SW indicated that the required visuomotor control in the latter situation resulted in elevated attentional demands. Hence, in conjunction our results suggest that the attentional costs of gait are more dependent on visuomotor factors than on the balance demands of walking.

O.5.6 Gait rather than cognition dominates the association with physical activity in incident Parkinson's disease

Sue Lord¹, Alan Godfrey¹, Brook Galna¹, Lynn Rochester¹

¹Newcastle University

BACKGROUND AND AIM: Physical Activity (PA) is important to health and may mitigate cognitive and motor decline. Recent evidence suggests it may also be neuroprotective for people with Parkinson's disease (PD). Most people with PD do not achieve recommended levels of PA even at this early stage [1], and drivers of PA are difficult to identify. The relative contribution of gait and cognition to PA has not previously been examined but both may impact. Understanding the relationship between these features and PA especially in early PD will guide interventions. METHODS: Eighty three people with PD (mean (SD) age 67.7 (9.3) years; 26 females) were recruited through an ongoing longitudinal study (ICICLE-PD). PA was measured for 7 days at baseline using a uniaxial accelerometer (ActivPALTM). PA outcomes included: Volume (proportion of time spent walking (%); number of steps accumulate in bouts > 100 steps); Pattern (\acute{a}); and Variability (S2) of walking bout duration. Participants were phenotyped by gait and cognitive deficit, based on the Motoric Cognitive Risk Syndrome [2] using slow gait (<1.1m/s) and impaired cognition (<26 on the Montreal Cognitive Assessment). Age, depression (Geriatric Depression Scale) and BMI were also assessed. Differences were examined using the Kruskal-Wallis test. RESULTS: Participants were phenotyped as follows: normal gait and cognition (n = 30); slow gait only (n = 15); impaired cognition only (n = 23); and slow gait and impaired cognition (n = 15). There were no differences in age, GDS or BMI. Between-group differences were significant for time spent walking (P = 0.027) and walking bouts >100 steps (P = 0.028). Walk PC time for participants with slow gait was 4.5 \pm



1.2 % and for participants with impaired cognition 6.0 ± 1.8 . Correspondingly, number of steps accumulated in bouts >100 was 12883 ± 8666 for participants with slow gait and 23028 ± 15506 for those with impaired cognition. DISCUSSION: Gait dominates the relationship with PA in early PD, relative to cognition. This may change over time as cognitive decline becomes more evident. Interventions need to focus on motor rather than cognitive skills to improve PA early on. [1] Lord, S. et al.(2013) J Neurol, 260; 2694-297. [2] Verghese et al (2014) Neurology, 83:1-9.

O.5.7 Stay focused! The effects of attentional focus on motor and motor-cognitive dual-task performance after acquired brain injury

Elmar Kal¹, John Van der Kamp², Han Houdijk², Erny Groet¹, Coen Van Bennekom¹, Erik Scherder²

¹Heliomare Rehabilitation, ²VU University Amsterdam

Background and Aim: Dual-task performance is often impaired in patients with acquired brain injury (ABI). A possible way to tackle this problem is to increase automatization of movement of patients, as more automatic motor control allows for better concurrent task performance. This may be achieved by manipulating attentional focus of patients. It has been shown that ABI patients are prone to focus internally on how they perform their movements. However, in healthy adults, substantial evidence shows that both single- and dual-task performance are (acutely) enhanced when performers focus externally on the effects of their movements, rather than internally. Therefore, this experiment set out to assess whether instructing ABI patients to focus externally also results in superior single- and dual-task performance. Methods: Forty individuals with chronic, unilateral ABI performed a cyclic one-leg flexion-extension task with both their paretic and non-paretic leg. The dependent variable was movement speed. In the external focus condition, participants were instructed to focus on where they placed their foot. In the internal focus condition, participants were instructed to focus on flexing and extending their knee. Participants performed both focus conditions in a counterbalanced fashion. Dual-task performance was assessed with two different cognitive dual-tasks: an auditory reaction time task and a letter fluency task. General estimating equations (GEE) were used to assess the effect of attentional focus on single task (movement speed) and dual-task (dual-task costs) performance. Possible confounding effects of patients' motor and cognitive functioning, and their inclination to engage in conscious motor control (e.g. use an internal focus) were assessed. Results: Single-task motor performance was similar in external and internal focus conditions ($B = -.95$, $p = .46$). In dual-task conditions, a trend ($B = -2.31$, $p = .065$) was found for better dual-task performance when patients focused internally. This effect was attenuated ($B = -1.91$, $p = .11$), however, when patients' tendency to engage in conscious motor processing was taken into account. Conclusions: Relative to an internal focus, an external focus does not seem to benefit single- nor dual-task performance of ABI patients. In fact, it may even be that an internal focus leads to better dual-task performance. This may be due to the majority of patients preferring to use such an internal focus in daily life. As this study only assessed acute performance effects, future work needs to address the long-term effects of learning with an internal or external focus of attention on dual-tasking post-ABI.



O.5.8 Association between Smartphone-based long-term Monitoring Outcomes and Traditional Clinical Assessment Tools in Community-Dwelling Older People

Sabato Mellone¹, Marco Colpo², Stefania Bandinelli², Lorenzo Chiari¹

¹University of Bologna, ²Azienda Sanitaria Firenze, Florence, Italy

BACKGROUND AND AIM: Personal Health Systems (PHSs), in the form of mobile systems like smartphones (SPs), can support and promote healthy lifestyles and help detecting early signs of movement and cognitive disorders. SPs are used in the framework of the FARSEEING project (farseeingresearch.eu) for gaining information on indoor and outdoor activities of daily living to ultimately define objective physical activity profiles. In this study we aimed to investigate the association between features derived from activities of daily living and well-established clinical tools for quantifying motor and cognitive impairments in a cohort of community-dwelling older subjects. **METHODS:** The study included 170 older subjects (80 ± 6.5 years old, 96 females) from the InChianti Study (inchiantistudy.net) wearing a SP at home for 5 to 9 days. The SP was worn on the lower back by means of an elastic belt and was equipped with a custom Android application designed for long-term monitoring of physical activity. A set of sensor-based features was extracted from the signals including the percentage of sedentary, active, and walking time, duration and intensity (metabolic equivalent, MET) of the activities, mean gait and turning characteristics. The following clinical data were collected from the subjects: depression (CES-D score), cognitive impairment (MMSE), essential elements of self-care (ADL), independent living in the community (IADL), physical performance (SPPB), number of medications, number of comorbidities, and fear of falling. Multiple Linear Regression models confounded by age, gender, and BMI were used for investigating the association between monitoring outcomes and clinical assessment tools. **RESULTS:** High SPPB scores were associated with a reduced sedentary time, and increased active and walking time. High SPPB scores and high MMSE were associated with an increased intensity of the activities, including gait, and changes of direction while walking showed a larger turning angle and faster turning speed. A high number of drugs was associated with a reduced intensity of the activities. Fear of falling and depression were associated with a reduced duration of the activities. Loss of independence was associated with a higher sedentary time and reduced active and walking time. No significant associations were found with the number of comorbidities. **CONCLUSIONS:** Outcomes of the SP-based home monitoring are coherent with clinical assessments performed in institutions supporting the hypothesis that SPs can become an effective solution for quantitative behavioural analysis with a clear clinical value. Wearable sensing by means of a SP can be a pervasive solution suitable for developing population-based approaches and new primary preventive strategies for community-dwelling older persons. **ACKNOWLEDGEMENTS:** Research leading to these results has received funding from the European Union 7th Framework Programme (FP7/2007-2013) under grant agreement FARSEEING n° 288940



O.6.1 Adjustment of the step prior to foot-off in a visuomotor task

Matthew Bancroft¹, Brian Day¹

¹University College London (UCL)

BACKGROUND AND AIM: During a step, vision plays a major role in guiding the foot towards its target after leaving the ground. Prior to this, the body's centre of mass is typically displaced forwards and laterally towards the non-stepping foot. This action is often termed an anticipatory postural adjustment (APA) but its function is unclear. We hypothesise that its role is to set the state of the body at foot-off to allow for a controlled fall towards the intended target during single stance. This predicts that the pre-step action will vary according to intended final foot position. Here we test this prediction by instructing subjects to step onto targets presented visually at different locations, both when the target remains stationary or switches to a new location prior to foot-off. **METHODS:** Six healthy, young participants stood in moderate darkness and stepped as accurately as possible to a floor-bound target light once it illuminated (Fig.1). The target lights were oriented so that step angle (medial, lateral targets) and length (distal, proximal targets) could be independently manipulated (Fig.1). In the majority of trials a random target illuminated and did not change location (direct condition). In 1/3 of the middle target trials (central of the five targets in Fig.1) the target unpredictably jumped 15cm to a new location, either medial, lateral, distal or proximal relative to the middle target (indirect condition). This jump was triggered on average 62 ± 49 ms (\pm SD) after throw onset, long before foot-off. Kinetics were recorded by force plates (Kistler) under each foot and summed to calculate total force on the body. Foot kinematics were recorded in 3D (Coda). **RESULTS:** When a target jump occurred, the stepping foot end-point deviated from the middle target in an appropriate direction (all $p < 0.001$, middle direct v indirect). Step foot end-point accuracy was unaffected in lateral, distal and proximal jump directions (all $p > 0.05$, indirect v direct) but medial jumps were typified by a slight overshoot in step length ($p < 0.001$, indirect v direct). For direct conditions, different throws were produced when stepping to different targets ($p < 0.001$). The greater the step angle, the greater the lateral force toward the non-stepping limb ($p < 0.01$) whilst the greater the step length, the greater the forward propulsive force produced ($p < 0.01$). When the target location changed, the throw was elongated by ~ 60 ms (593 ± 96 ms indirect vs 532 ± 74 ms direct, $p < 0.01$). **CONCLUSION:** The results show that the pre-foot-off phase of a step can be adjusted using vision and is dependent on the final location of the step, both in terms of different step lengths and angles. If the pre-foot-off phase of a step was functionally unimportant it would be expected that no step adjustment would occur until after foot-off. The results therefore suggest that the pre-foot-off throw of the body mass (APA) plays a functionally important role in a step.

O.6.2 Foot placement adjustment is not always required for recovery in perturbed walking

Mark Vlutters¹, Edwin Van Asseldonk¹, Herman van der Kooij¹

¹University of Twente

BACKGROUND AND AIM: Foot placement is considered the most important strategy for balance during walking [1]. Various concepts such as the XCOM [2] suggest a foot placement location relative to the



center of mass (COM), proportional to the COM velocity. Yet, altered foot placement is only effective if the adjustment aids in generating the desired forces after foot contact. Hence, following a perturbation there might be no need to adjust the foot location as long as these forces can be delivered, even if the COM velocity changes. Here it was investigated how the COM velocity at right heel strike (HSR) relates to the stepping location at HSR, and to the time average horizontal ground reaction forces (mGRF) delivered in the subsequent double support (DS) phase, following perturbations during walking. METHODS: Ten healthy young adults walked on an instrumented split-belt treadmill (2.25 km/h). Subjects wore a pelvic brace which was connected to a motor and lever arm (0.3 m) using a rigid rod. The motor was located to the right or rear of the treadmill (fig. 1). During free walking the motor was controlled such that the interaction force with the subject was minimal. A 150 ms perturbation was applied at randomly selected right toe-offs, such that the next step was with the right leg. Perturbation magnitude was equal to 4, 8, 12 or 16% of the subject's body weight. Both medio-lateral (ML) and antero-posterior (AP) perturbations were applied. Kinematic data of the feet, lower legs, upper legs, pelvis, trunk and head were collected using a motion capture device. Furthermore, 3 degree of freedom forces were collected using the treadmill's force plates. All position data were expressed relative to the COM, estimated from the kinematic data. Using the belt speed and the global COM position, the COM velocity relative to the walking surface was determined. All data were scaled and made dimensionless following [3]. RESULTS: Here only AP results are shown. The forward and backward perturbations lead to increases and decreases in COM velocity respectively (fig. 2). Despite the various COM velocities at HSR, subjects kept the distance to the leading (right) foot similar to that in unperturbed walking (fig. 3A). However, in the subsequent DS phase subjects exerted increasing breaking forces (negative) for increasing forward velocity, whereas propulsive forces (positive) were delivered for velocities lower than in unperturbed walking (fig. 3B). Several backward perturbations (-0.04, -0.08, -0.12) might have been corrected before DS, as neither velocity nor mGRF appears to deviate from the values in unperturbed walking. CONCLUSIONS: Foot placement adjustment is not required as long as the forces following foot placement can counteract the perturbation. This has implications for foot placement prediction, as it should be taken into account to what extent the desired forces can be delivered after foot contact. 1)MacKinnon 93 J.Biom 2)Hof 05 J.Biom 3)Hof 96 G&P

O.6.3 Motor cortex excitability, attention networks and muscle synergies during single & dual task walking in elderly

Eling de Bruin¹, Natalie Müller¹, Rolf van de Langenberg¹

¹IBWS ETH

Background and Aim: Coordination of walking is based on a small set of muscle synergies: groups of muscles simultaneously activated in fixed ratios by the nervous system [1,2]. Analyzing muscle synergies might enable gaining new insights into the neural substrates underlying gait control and, hence, enable development of new targeted therapies [2]. This study aimed to identify the correlation between gait related muscle synergies, motor cortex excitability and attention networks in healthy elderly. METHODS: Muscle synergies from 55 community dwelling older adults were extracted from Electromyography recordings of eight leg muscles while single and dual task walking (preferred walking speed). Efficiencies



of three specific attention networks (alerting, orienting, executive control) were determined using the Attention Network Test (ANT). Motor cortex excitability was assessed by means of transcranial magnetic stimulation (TMS). Linear regression analysis assessed correlations between variables. RESULTS: Data from 26 women and 22 men (75 ± 7.4 year; range 65-92 years) could be included in the final analysis. To determine the number of walking modules, muscle synergies were extracted separately from each walking condition with regard to the actual number of synergies required to account for at least 90% total variability and 75% variability in each muscle. For single task walking we identified 3.1 ± 0.84 modules and for dual task walking, 3.0 ± 0.67 modules on average. For single task walking 20.8% of the participants required two, 54.2% three, 16.7% four and 8.3% five muscle synergies. For dual task walking 22.9% of the subjects required two, 56.3% three and 20.8% four muscle synergies. Muscle coordination complexity during dual task walking is explained by alerting efficiency ($p < .05$) but not by orienting, executive control or motor cortex excitability. No significant correlations were found for single task walking and any selected predictors. CONCLUSIONS: Gait pattern complexity expressed by the number of muscle synergies is associated to alertness efficiency in dual task walking. Gait complexity is not affected by orienting, executive control functions or motor cortex excitability, neither in dual nor single task walking. REFERENCES 1. Chvatal & Ting. Common muscle synergies for balance and walking. *Front Comput Neurosci* 2013, 7:48 2. Ivanenko YP, Poppele RE, Lacquaniti F: Five basic muscle activation patterns account for muscle activity during human locomotion. *The Journal of Physiology* 2004, 556(1):267-282. 3. Safavynia et al. Muscle Synergies: Implications for Clinical Evaluation and Rehabilitation of Movement. *Topics in spinal cord injury rehabilitation* 2011, 17(1):16-24.

O.6.4 Multi-limb coordination for lateral stabilization of one-legged balance

Amy Wu¹, Arthur Kuo¹

¹University of Michigan

BACKGROUND AND AIM: Humans stabilize their balance through a variety of actions, including adjustment of center of pressure and movement of the limbs. Although the nominal balance strategy has been well characterized (Hof 2007), few studies have considered how multiple limbs should be coordinated and in what ways to keep the body stabilized. The nominal coordination strategy may also become infeasible due to environmental conditions, such as reduced base of support (BOS), and thus require adjustments. We propose a simple balance model based on angular momentum principles to explain limb coordination and show that humans compensate for BOS constraints by adjusting feedback gains between body segments. METHODS: We determine a simple control law for controlling balance through inertia from a multi-inverted pendulum model. Stabilization of the stance leg about vertical requires that torques be exerted against the inertia of the trunk, arms, and opposite leg. Impulse-momentum principles dictate that the net torque acting on body segments, which is equal and opposite to the restoring torque on the stance leg, should be in the same direction as the angular displacement of the stance leg from upright. Defining feedback gain as torque on segment divided by stance leg displacement, the net gain should be positive for stability. With reduced BOS, the range of center of pressure (COP) excursion is restricted. This limits stance foot torque and should be compensated for using greater gain from elsewhere in the body. RESULTS: To test our hypothesis against experimental



observations of human balance, control gains were empirically identified from subjects balancing on one leg (N=9). To test how constraints affect balance, subjects stood on blocks of different widths to limit stance foot torque on the stance leg. The signs of the gains related to stance leg angle were consistent with our prediction that the free limbs should be rotated in the same angular direction as the displaced stance leg (Figure 1). Nominally, stance foot (COP) produced the dominant gain. However, when the base of support was reduced, larger gains from other available limbs were utilized for balance. The trunk, in particular, contributed 72% of the net gain at the narrowest BOS condition compared with 12% at the normal BOS condition. The other body segments may help balance, but their relatively low mass seems to correlate with the small size of their gains. **CONCLUSIONS:** Multiple limbs contribute towards one-legged balance by rotationally accelerating in the same angular direction as the displaced stance leg. To accommodate task constraints, humans amplify the overall gain and redistribute feedback gains among the unconstrained limbs. Other than the stance foot, the trunk appears to have the largest contribution towards the restoration torque on the stance leg with a gain modulated based on the base of support.

O.6.5 The effect of restricting arm movements on gait stability in children with Cerebral Palsy and Typically Developing children

Pieter Meyns¹, Sjoerd Bruijn², Kaat Desloovere³, Hilde Van Waelvelde¹

¹UGent, ²VU Amsterdam, ³KU Leuven

BACKGROUND AND AIM: There is some debate about the role of the arm movements during walking in humans[1]. In healthy adults, multiple roles have been suggested, including optimizing stability of gait[2]. However, studies using perturbation experiments do not corroborate this suggestion, and even found negative effects of arm swing on gait stability[3,4]. On the other hand, these studies did indicate that the arms may aid in recovery of the gait pattern after a perturbation. Specifically in toddlers[5] and children with Cerebral Palsy (CP)[6], the typical 'guard' arm posture during walking has been described, which has been proposed to be a compensatory strategy to maintain stability during walking. However, to date, the effects of arm swinging on gait stability in these children remain unclear. To assess whether arm movements have a functional role during gait in CP, the effect of having the arms free or restricted to swing on stability was evaluated in hemiplegic (HEc) and diplegic (Dlc) children with CP, and compared to typically developing children (TDC). It was hypothesized that arm restriction would affect stability mainly in CP. **METHODS:** Participants included 11 spastic HEc, 14 spastic Dlc and 24 TDC (4-12yr). Participants were asked to walk with the arms free or crossed over the abdomen. Total body kinematics were recorded during preferred and fast walking. Medio-lateral Margins of Stability (MoS) were determined as a measure of balance. MoS was calculated as the distance between the extrapolated centre of mass and the limits of the base of support[7]. A repeated measures ANOVA with Group as a factor, Arm condition as a repeated measures factor, and walking speed as covariate was used. Tukey's post hoc comparisons were applied ($\alpha = 0.05$). **RESULTS:** Crossing the arms significantly increased MoS (main effect of Arm, $p=0.001$). MoS in Dlc was significantly increased compared to TDC ($p<0.001$), while this was not significant for HEc ($p=0.17$; main effect of Group, $p<0.001$). The interaction effect of Arm*Group ($p=0.045$) indicated that TDC showed a significantly larger decrease in MoS during



walking with the arms free than the two CP groups. CONCLUSIONS: When the arms were unable to move freely, all children (TDc and CP) increased their MoS. These results show that both TDc and CP children experience adverse effects on gait stability when arm movements are restricted. When the arms were restricted, children relied on other strategies (i.e. increasing base of support) to maintain stable. Even though Dlc were the most unstable group when walking with the arms freely, both Dlc and HEc showed similar increases in MoS due to restricting the arm movements, while this effect was larger in TDc. REFERENCES 1 Meyns P et al Gait Posture 2013 2 Ortega J et al J Biomech 2008 3 Bruijn S et al J Exp Biol 2010 4 Pijnappels M et al Exp Brain Res 2010 5 Ledebt A. Infant Behav Dev 2000 6 Meyns P et al Eur J Paediatr Neurol 2012 7 Hak L et al PloS One 2013

O.6.6 Rhythm perception and production abilities relate to motor impairment and temporal gait variability after stroke.

Kara Patterson¹, Svetlana Knorr², Jessica Gran³

¹University of Toronto, ²Toronto Rehabilitation Institute - UHN, ³Western University

BACKGROUND & AIM: Healthy gait features regular, reciprocal movement and thus has an inherent rhythm. In contrast, post stroke gait features increased spatiotemporal variability and asymmetry and thus can be described as having impaired rhythm. A case report suggests rhythm abilities (e.g. tapping to music) are impaired after stroke[1] but little is known about the association of impaired rhythm abilities with motor and gait impairments after stroke. The study objectives were to 1) compare rhythm abilities after stroke to healthy older adults and 2) explore relationships between rhythm abilities and stroke motor and gait impairments. METHODS: Individuals with subacute stroke (n=19) were recruited. A rhythm perception test required participants discriminate whether tones overlaid on musical stimuli were on the beat of the music (yes/no; % correct). A rhythm production test required participants tap to the beat of musical stimuli with the unaffected hand. Performance was measured as tap timing variability (coefficient of variation; CoV) and deviation of tap timing from the music beat (Interbeat Interval Deviation; IBI). Spatiotemporal gait variability (swing & stance time standard deviation (SD), step width & length SD) and symmetry (step length and swing time ratio) were measured with a pressure sensitive mat. Cognition, stroke severity and leg and foot motor impairment were measured with the Montreal Cognitive Assessment (MoCA), National Institutes of Stroke Scale (NIHSS) and Chedoke McMaster Stroke Assessment (CMSA) respectively. RESULTS: Mean age was not different between the stroke (66±14yrs) and healthy (65±8yrs) groups (p=0.77). Rhythm perception accuracy was worse in the stroke group (54.3±15.4%) than the healthy group (73.7±14.1%) (p<0.001). Within the stroke group, perception accuracy was correlated with CMSA foot score (r=0.48, p=0.04). Rhythm tapping measured by CoV was correlated with swing time variability (r=0.58, p=0.02). CONCLUSIONS: Rhythm abilities are impaired after stroke and these impairments relate to motor and gait deficits. Motor impairment of the foot may suggest stroke-related damage to motor areas in the brain which have been linked to rhythm abilities[2]. As rhythm perception did not correlate with NIHSS or MoCA, the association with CMSA does not reflect a simple link between stroke severity and performance on all behavioural tests. Impaired rhythm production may prevent individuals with stroke from generating a rhythmic walking pattern resulting in increased temporal gait variability. These results may have implications for the use



of auditory rhythmic stimuli to cue motor function in post-stroke gait rehabilitation. Future work will explore brain activity related to rhythm processing after stroke. REFERENCES: [1] Fries W, Wihart AA. *Neuropsychologia*, 1990. [2] Grahn JA, Brett M. *J Cognitive Neurosci*, 2007.

O.6.7 Do muscle strength and force development differ according to functional abilities in healthy elderly men?

Charlotte Pion¹, Lucas Goulet¹, Éric Demers¹, Sébastien Barbat-Artigas¹, Olivier Reynaud¹, Stéphanie Chevalier², Pierrette Gaudreau³, Gilles Gouspillou¹, José Morais², Mylène Aubertin-Leheudre¹, Marc Bélanger¹

¹Université du Québec à Montréal, ²McGill University, ³Université de Montréal

Background and aim: Aging leads to a loss of muscle strength and functionality likely resulting from a combination of neural and muscle dysregulations. The aim of the present study was therefore to determine if muscle strength and force development differ depending on functional status in healthy elderly men. Methods: Seventy-four men were divided in two functional groups based on a functional ability (FA) score derived from 6 tests of the Short Physical Performance Battery (Normal and fast 4m-walk tests, normal and fast Timed-up and go, chair and stair tests). Extensor strength of the lower limb (LL) was obtained for concentric (CES; 1-Maximal Repetition [MR]) and isometric (IKES; right knee extension) contractions. Lean masses of LL (LLLM) and right thigh (TLM) were measured using DXA and combined with the strengths to yield concentric (CES/LLLM) and isometric (IKES/TLM) strength indices. A neurophysiological profile was established from: the spinal excitability (Hmax/Mmax ratio); motoneuron conduction velocity (CV); the completeness of muscle activation (% of force reserve; %FR) during a 2s right Quadriceps Femoris maximal voluntary isometric contraction (MVC); median power frequency (MPF) and mean amplitude (MA) of the Vastus Lateralis (VL) EMG signal during MVC and at the beginning and the end of muscle fatigue test (FT; 2s of contraction and 1s rest until a force of 50% of the MVC). A muscular profile was obtained from: ascending and descending force slopes during the MVC; VL muscle twitches parameters [amplitude, contraction and ½ relaxation times]; the knee joint angle (KA) and velocity (KV) as well as MPF and MA of the EMG were determined for a sit-to-stand functional evaluation; muscle phenotype (fiber proportion and size from right VL biopsy samples). Results: No difference was observed between the two groups for the following: age, BMI, LLLM and TLM, Hmax/Mmax ratio, CV, the MPF and MA of the EMG for the sit-to-stand condition, twitch parameters and muscle phenotypes. In contrast, strengths and force indices, ascending and descending force slopes for MVC, KA and KV during the sit-to-stand evaluation and FT parameters were all significantly ($p < 0.05$) lower in the low FA group compared with the high FA group. The high FA group tended ($0.05 < p < 0.1$) to have higher EMG MPF and MA for the MVC but lower %FR. Conclusion: In older man of similar age, strength and force development appear to differ with functional status. The absence of significant differences in muscle phenotypes, lean masses, twitch parameters indicate similar muscular profiles between the 2 groups. Furthermore, similar spinal excitability and motoneuron CV suggests that muscle strength and force development differences may not be of spinal or peripheral origins. In contrast, the lower values in the low FA group suggest that the lower strength associated with a poorer functionality in elderly healthy men may be due to a deterioration of the central motor command.



O.6.8 Vertical ground reaction force during walking: Are they related to bone mineral density left right asymmetries?

Marina Brozgol¹, Mira Arbiv¹, Aner Weiss¹, Anat Mirelman¹, Jeffrey Hausdorff¹, Nachum Vaisman¹

¹Sourasky Medical Center

BACKGROUND AND AIM: It is commonly assumed that there is minimal variation between the bone mineral density (BMD) of both hips. Until recently, screening was only done on one side, but due to technological development, studies are now concurrently done on both hips. Dual-energy X-ray absorptiometry (DEXA) scan is routinely used to evaluate BMD for the clinical diagnosis of osteoporosis. During standard BMD screening, we noticed significant differences between hips in about 10% of the cases. The purpose of the current study was to determine whether asymmetrical femoral neck BMDs are also associated with asymmetrical gait. **METHODS:** The study population included subjects with a left-right difference higher than 0.5 SD in BMD between hips and normal controls (less than 0.3 SD). Exclusion criteria included any known neurological disease, leg operation, peripheral neuropathy and orthopedic problems. Subjects were asked to walk for 1 minute at their comfortable speed while outfitted with the Pedar[®] pressure sensitive insole system (novel GmbH). For each gait parameter, we calculated an asymmetry index: GA (Gait Asymmetry) = $|\ln(XL/XR)| * 100\%$. With this definition, values of 0.0 reflect perfect symmetry and higher values reflect greater degrees of asymmetry. **RESULTS:** The asymmetrical BMD group consisted of 36 participants (9 males; age 62.2 ± 9.89 years; BMI: 25.86 ± 5.28 ; Z scores between hips: 1.08 ± 0.52). The symmetrical BMD group consisted of 9 participants (2 males; age 59.58 ± 5.1 years; BMI: 25.54 ± 4.31 ; Z scores between hips: 0.17 ± 0.12). Most of the subjects were not aware of any difference between hips that could otherwise readily explain any gait asymmetries. The asymmetry indices of mean force, max force, step duration and swing time were significantly higher in the asymmetrical BMD group, compared to the symmetrical BMD group ($p < 0.01$). Swing time difference (RSWT-LSWT) between left and right feet were correlated with BMD delta Z scores (Spearman's correlation = 0.38, $p = 0.02$). (Initial analyses found no association between the side with lower BMD score and lower weight bearing (based on the ground reaction forces). **CONCLUSIONS:** These preliminary findings suggest that asymmetries in BMD of the hips are associated with asymmetries in gait parameters and in the vertical ground reaction forces. These differences are likely not the effect of nutrition, metabolism, or lifestyle which similarly affect both hips. Future work should aim to identify the mechanisms underlying the relationship between these asymmetries (e.g., does one cause the other?), if gait and balance testing can aid in the early detection of compromised bone health, and whether appropriate gait training and exercises that alleviate gait asymmetries may reduce BMD asymmetries.



O.7.1 Kinematic validation of the Interactive Walkway against a gold-standard reference system

Daphne Geerse¹, Melvyn Roerdink¹, Bert Coolen¹

¹MOVE Research Institute Amsterdam

Background and aim The Interactive Walkway (IWW) is a 10-meter walkway augmented with gait-dependent visual context for an assessment of overground gait and gait adaptability. The walkway is equipped with multiple integrated Microsoft Kinect v2 sensors for markerless 3D motion registration. Additionally, a projector presents gait-dependent visual context on the walking surface, such as obstacles and stepping targets, based on real-time processed 3D gait data. A key asset of the IWW is its possibility to conduct standardized clinimetric gait tests (e.g., 10-meter walking test [10MWT]) and gait adaptability assessments, while simultaneously obtaining quantitative gait information. The aim of this study is to validate the IWW by comparing both raw body point's time series as well as derived quantitative gait measures against a gold standard reference system. **Methods** A heterogeneous group of 21 healthy participants performed a standard clinimetric gait test (i.e., 10MWT) and assessments of gait adaptability (i.e., obstacle avoidance, targeted stepping and sudden stops and starts). Body point's time series were recorded with the IWW and Optotrak system, from which quantitative gait measures were derived (e.g., walking speed and step length). The main outcome measures of this study were the agreement between the two motion registration systems for detrended time series of body points in the walking direction and the agreement between quantitative gait measures. Although the IWW allows for full-body 3D motion registration, the focus of this study was on the time series of the ankle joints and thereof derived gait parameters. **Results** The results of the 10MWT and assessments of gait adaptability indicated that the IWW time series have an excellent agreement with Optotrak time series for both the left ($ICC(A,1) = 0.956$) and right ankle ($ICC(A,1) = 0.934$). With regard to the quantitative gait measures, an excellent agreement was found for time to walk 10 meters ($ICC(A,1) = 0.999$), walking speed ($ICC(A,1) = 0.955$), step length ($ICC(A,1) = 0.963$) and cadence ($ICC(A,1) = 0.970$). However, a moderate agreement was found for step width ($ICC(A,1) = 0.775$). **Conclusion** This study has shown that IWW body point's time series, stemming from the Kinect v2 system, have an excellent agreement with those of a gold standard reference system. In addition, most quantitative gait measures can reliably be estimated using the data of Kinect. Consequently, since Kinect-based 3D data registration is markerless and hence time-efficient and patient friendly, the IWW may be very promising for clinical settings. Future aims and directions for the IWW include assessing gait and cognition for gait-environment interactions (e.g., sudden stops, turning under time pressure, obstacle avoidance) and validation of encompassing clinical gait evaluation protocols for various patients groups (e.g., Parkinson's disease, stroke, fall-prone elderly).

O.7.2 Where are the parameters? A sensitivity analysis of an inverted pendulum balance control model

Jantsje Pasma¹, Tjitske Boonstra², Vasiliki Spyropoulou², Alfred Schouten²

¹TU Delft, ²Delft University of Technology



Background & Aim During bipedal stance, corrective joint torques are needed to counteract the destabilizing gravitational torque and to maintain upright posture. To investigate how humans generate the corrective torques and to identify possible underlying causes of balance disorders, balance control models have been developed. These models contain various parameters to describe balance behavior; for example smaller body excursions could result from increased system stiffness. Theoretically, differences in the values of the balance control parameters could provide insight into pathophysiological changes in certain patient groups. However, even after fitting a model to experimental data, the relative contribution of each parameter to specific frequency bands is not directly evident. Therefore, a sensitivity analysis was performed, with the goal to identify the unique contribution and the relative importance of the model parameters to describe balance behavior. **Methods** An inverted pendulum balance control model was used in the model simulations. The balance behavior was expressed with frequency response functions (FRFs), representing the dynamic relationship between external sensory perturbations (e.g. support surface rotations) and the response (e.g. body sway) as a function of frequency, in terms of amplitude and timing. The analyzed model FRF included the following parameters: the human body mass (m), moment of inertia (J) and center-of-mass height (h); the passive muscle stiffness (K) and damping (B); the sensory weighting factor (W); the neural controller's proportional and derivative feedback gains (K_p , K_d) and time delay (τ_d); the muscle activation dynamics' bandwidth (ω_0) and relative damping (β) and the force feedback's gain and time constant (K_f , τ_f). The sensitivity of each parameter of the balance control model was determined for both the FRF magnitude and phase through the analytically obtained partial derivative, using the Matlab symbolic toolbox (Mathworks). Here we focused the sensitivity analysis on the main feedback parameters: K , τ_d , W , K_p and K_d . **Results** The sensitivity analysis showed that both K and K_p parameters shape the FRF in the lower frequency range (0.1-1 Hz). Additionally, the K_d parameter has a distinct influence on the FRF, by shaping the peak and slope in the 0.5-0.9 Hz range. Furthermore, W influences the overall magnitude of the FRF, without any apparent frequency dependency, and does not have any effect on the phase. Conversely, the effect of τ_d is more difficult to recognize in the FRF magnitude, and becomes apparent in the phase above 0.6 Hz. **Conclusions** It is possible to uniquely determine the value of the sensory weighting factor, the time delay, the derivative gain, and the lumped sum of the passive and active stiffness, making the used balance control model suitable to determine differences in these parameters in different patient groups.

0.7.3 Mechanisms of interpersonal sway synchrony and stability

Raymond Reynolds¹

¹*University of Birmingham*

Touching another standing person reduces sway(1), but how this could be anything other than deleterious for postural control is uncertain. Here we explain the mechanisms underlying interpersonal sway interactions by a combination of experiment and modelling(2). The experiment comprised 8 pairs of volunteers engaging in three levels of physical contact: No Contact, Light Touch, Shoulder Grasp (Fig. 1A), combined with four visual conditions; Both Eyes Open (EO), Both Eyes Closed (EC), EO/EC, EC/EO. Sway was quantified as RMS sagittal COP velocity over 60s. To determine the magnitude/timing of



interactions we computed COPv cross-correlations. We then developed a Simulink model to explain the empirical observations, consisting of an inverted pendulum under PID control. Two models were coupled to mimic interpersonal interactions; Light touch (and visual interaction) was simulated by coupling the feedback loops; Shoulder grasp was modelled by physically linking the pendulums. The model generated COPv cross-correlations for direct comparison with the empirical data. Parameters were automatically varied to best match to the empirical data. Light touch reduced sway by up to 17% relative to no contact, and shoulder grasp reduced it further, up to 37% (Fig. 1B). These beneficial effects were greatest when making contact with a more stable partner (i.e. EC subject contacts EO partner; vision x contact interaction: $F_{6,42}=108; p<0.001$). Cross-correlation twin peaks revealed that, during light touch and/or visual contact, each subject followed their partner with a delay of $\sim 0.4s$ (Fig. 1C). In contrast, shoulder grasp was characterised by a single prominent peak at zero lag. Our model recreated these cross-correlations with remarkable fidelity, with physiological plausible delays in the feedback loop. Furthermore, the model predicted sway reductions from both forms of physical contact, albeit less than observed empirically. The empirical data demonstrated a beneficial effect of physical contact which was greatest when contacting a more stable person. The cross-correlation peaks suggest the effects of light touch/vision and shoulder grasp are explained by sensorimotor and mechanical coupling, respectively. This is corroborated by the model, which employed these mechanisms to accurately recreate the data. Furthermore, the model suggests no simple leader-follower relationship during interpersonal sway, whereby each person might periodically switches roles; the data were recreated by a linear time-invariant model. Finally, it is unnecessary to disambiguate self from partner motion to derive any benefit from physical contact; in our model each person assumed the other to be a fixed reference point. However, since the model reduced sway less than that empirically observed, this suggests additional mechanisms may be in place to identify self versus partner motion. 1. Johanssen L, Wing AM, Hatzitaki V. *J Neurophys* 2012 2. Reynolds RF, Osler CJ. *J Roy Soc Interface*

O.7.4 The human subthalamic nucleus recruits single neurons for kinematic control using different strategies for movements of upper vs. lower extremities

Ariel Tankus¹, Anat Mirelman², Nir Giladi¹, Itzhak Fried³, Jeffrey Hausdorff¹

¹Tel Aviv Sourasky Medical Center and Tel Aviv University, ²Tel Aviv Sourasky Medical Center, ³Tel Aviv Sourasky Medical Center and Tel Aviv University and UCLA

1. Background and aim Human feet perform very different tasks than hands. In spite of their different functional role, the gait and hand motor control networks share multiple brain areas, such as the subthalamic nucleus (STN), but differ at the sub-region level, for example: the somatotopic organization of the STN. Although subthalamic neuronal activity has been related to tremor, hand gripping force, target appearance event, and movement onset and direction, differences in subthalamic neuronal recruitment for kinematic control of hand vs. gait movements are unclear. Our research is therefore aimed to study single unit recruitment strategies in the STN for upper vs. lower extremity movements. 2. Methods Participants in our study were 7 Parkinson's disease patients undergoing implantation of deep brain stimulator for treatment of their motor symptoms (mean: 57 years old, $SD=10.6$). During the surgery, patients performed hand and feet tapping movements by one limb, bipedally or bimanually (in



an alternating pattern). Each type of tapping was repeated at 3 paces: patient self-selected "normal" pace, slow pace, and fast pace. During the tasks, patients wore small, light, wireless measurement devices (Opal monitors; APDM, Inc.) that recorded kinematics in synchrony with the neuronal recording: acceleration, angular velocity and orientation. In parallel, the activity of single STN units was recorded (Neuroguide, Alpha-Omega, Nazareth, Israel). 3. Results We recorded the activity of 61 single units in the STN of 7 Parkinson's disease patients intra-operatively. For feet movements, both uni- and bi-pedal, normal, patient-selected, pace recruited the largest percentage of units (mean: 92%, SE: 2.5%). A significantly smaller percentage was involved in slow pace movements (mean: 87%, SE: 3.1%; $p=0.025$, paired-sample t-test), and an even smaller, in fast movements (mean: 77%, SE: 3.6%). For hand movements, the largest percentage of the neurons involved was during the slow pace (mean: 85%, SE: 1.9%), followed by a significantly smaller percentage during normal pace (mean: 77%, SE: 1.8%; $p=0.024$, paired-sample t-test), and the smallest percentage again for the fast pace (mean: 73%, SE: 2.9%). 4. Conclusions The difference in neuronal recruitment during normal and slow paces between feet and hand movements may be due to the different roles of the human upper and lower limbs in the expression of cognitive processes. Whereas hand movements are commonly used to express the results of cognitive processes by fine object manipulations, and may therefore involve more neurons, feet movements, especially gait, on the other hand, are indirectly affected by such processes via reduced attention to gait during dual tasking. Support: I-CORE, TASMC excellence grant to Ariel Tankus.

0.7.5 Ankle trajectories for the quality and variability of semi-free-living gait in older adults, using a single ankle-worn inertial sensor

Kejia Wang¹, Michael Del Rosario¹, Sylvain Hirth¹, Kim Delbaere², Matthew Brodie², Nigel Lovell¹, Lauren Kark¹, Stephen Lord², Stephen Redmond¹

¹UNSW Australia, ²NeuRA

BACKGROUND AND AIM: Gait analysis is important for assessing mobility and fall risk in older adults, but supervised clinical assessments may be limited by the Hawthorne effect, low space, subjectivity and bulky equipment. Wearable magnetic and inertial measurement units (MIMUs) are an attractive tool, being mobile, non-invasive and objective. Existing studies using MIMUs have reported simple spatiotemporal measures, but often inferred gait cycle events, or were limited in sample size or location. To gain insight into gait in semi-free conditions by tracking the ankle precisely through space, we present measures of gait variability within and between older adults, using a validated attitude heading and reference system (AHRS) and dead reckoning to mark out the ankle trajectory during unscripted gait. **METHODS:** Ninety-two older adults (age 84.1 ± 3.9 years, 50 male) completed semi-supervised walking bouts totaling 290 m, broken up between other daily activities and rests, in a self-selected manner. They wore an MIMU on the right ankle (containing a triaxial accelerometer (± 6 g), triaxial gyroscope (± 2000 rad/s) and triaxial magnetometer (± 6 gauss)). An AHRS algorithm used these nine data streams at 128 Hz to estimate sensor orientation in the global frame. The ankle trajectories were estimated per step by dead reckoning between automatically detected heel-strikes. This procedure was validated with an optical motion capture system (Vicon) using three subjects (age 20-22) over two 5 m walks each, to be accurate within 1.2% for step height (h) and 6.8% for step length (sL). Eighteen



measures of gait quality and variability were calculated for the older adults over their walks. These were the mean of: sL; step width (sW); swing speed (u); h; path length (pL); and swing time (sT); and for each of these six parameters, inter-subject variation (standard deviation (SD) over all subjects) and mean intra-subject variation (subject-specific SD across steps). All lengths were normalised to body height. The Lilliefors test was used to check for normality and skewness was calculated. RESULTS: There was strong evidence that intra-subject variation in sL, u, sT and pL were not normally distributed ($p < 0.001$) (see table). Our parameter values are comparable to reported values in similar studies, but we found lower mean sW and sL, slower u, greater u variation and greater h. Mean intra-subject variation was comparable to inter-subject variation but lower by ratio for all parameters except sW. CONCLUSIONS: Measuring gait parameters from ankle trajectories using a single MIMU is feasible in a semi-free setting; natural gait is variable both between and within individuals and parameters may not be normally distributed, so analyses on free-living data must allow for these factors. Future work will analyse similar parameters from in-laboratory gait (such as in the 6 m Walk and the Timed Up and Go Test) to quantify any differences compared to gait in a free environment.

O.7.6 Muscle activity during walking measured using FDG-PET and 3D MRI segmentations

Vivian Weerdesteyn¹, Sjoerd Kolk¹, Edzo Klamer², Jan Schepers³, Eric Visser¹, Nico Verdonchot¹

¹Radboud University Medical Centre, ²University of Twente, ³Materialise N.V.

BACKGROUND AND AIM: In gait analysis, surface electromyography is commonly used for measuring muscle activity. This method has limitations in that it reflects the activity of only a subset of motor units within the muscle of interest, and it does not provide information on muscles that lie more deeply inside the leg. The purpose of this study was to determine the contribution of each muscle in the lower limbs to walking using [18 F]fluorodeoxyglucose (FDG) positron emission tomography (PET) in combination with new MRI image analysis techniques. FDG accumulates in muscles that are active during walking, thereby allowing detailed study of muscular activity in walking regardless of whether a muscle is situated superficial or deep inside the body [1]. METHODS: Ten healthy subjects walked on a treadmill at self-selected comfortable walking speed (1.26 ± 0.11 m/s) for a total of 90 minutes, 60 minutes before and 30 minutes after intravenous injection of 50 MBq FDG. A PET/CT scan of the lower limbs was made subsequently. The three-dimensional contours of 78 muscles in the lower limbs (39 per limb) were semi-automatically determined from MRI scans using Mimics (Materialise N.V., Leuven, Belgium). After non-rigidly registering the MRI to the CT scans we superimposed the muscle contours on the PET scans and extracted FDG uptake values, which were corrected for body weight, injected dose and muscle volume. The results reflect the amount of FDG in each muscle, relative to the total amount of FDG in all 78 muscles of the lower limbs. RESULTS: The muscles with the highest median uptake were the soleus, gluteus maximus, vastus lateralis, gastrocnemius medialis, adductor magnus, and gluteus medius (Table 1). We found a wide range of FDG uptake values between subjects, including in some of the more important muscles involved in walking (e.g. soleus, gluteus medius, gastrocnemius medialis). Between the limbs, large asymmetries in FDG uptake (expressed as % of average uptake between left and right) were observed in hip and lower-leg muscles, e.g. soleus (absolute mean difference (AMD): 23%), tibialis anterior (AMD: 43%), gluteus medius (AMD: 19%) and gluteus minimus (AMD: 31%). The thigh muscles



exhibited a relatively symmetrical uptake between the limbs (AMD: 3-10%). CONCLUSIONS: Our data indicate the potential of FDG-PET for the investigation of muscular activity during walking. The distribution of FDG among the muscles (including prime movers) varied between subjects, pointing to inter-subject differences in muscle activation patterns. Interestingly, large asymmetries in uptake between the limbs were observed in these healthy subjects, even though their gait visually appeared to be symmetrical. The differences in uptake observed in the prime movers and between the limbs are of particular interest for validating subject-specific musculo-skeletal models. Reference [1] N. Oi, et al., J Orthop Sci, 2003;8:55-61.

O.7.7 Effect of Lab Environment and Segment Angular Velocity on the Accuracy of Orientation Data Issued from Inertial Measurement of Motion in a Clinical Biomechanical Evaluation Context

Karina Lebel¹, Patrick Boissy¹, Christian Duval¹

¹Université de Sherbrooke

Background & Aim: Attitude and heading reference system (AHRS) consists of a set of inertial sensors (accelerometers, gyroscopes and magnetometers) whose outputs are fed into a fusion algorithm in order to deduce the orientation of the device in a global reference frame based on gravity and magnetic North. Popularity of AHRS as motion tracking devices for biomechanics has been growing rapidly over the past few years. However, studies on the accuracy of such systems are limited and often lead to differing conclusions, which raises some questions about the effect of environment and the type of motion on the accuracy of AHRS. This study therefore aims at evaluating the impact of environment and angular velocity of segments on the accuracy of orientation data issued by AHRS. Methods: 10 participants (mean_age = 50.9 years old) performed a Timed-Up and go along two different paths in the laboratory (a magnetically clean path, MC and perturbed path, PP) at varying speeds, repeatedly (n=3 trials/condition). AHRS modules (ISG-180, Synertial) were positioned on multiple segments (head, upper trunk, pelvis, thigh, shank and foot). Rigid bodies with markers were secured to AHRS modules and tracked simultaneously by an optical motion analysis system used as a gold standard (Vicon Motion System). Absolute accuracy (AC), corresponding to the change in orientation of a segment, and relative accuracy (RA), referring to the accuracy in the tracking of a change in orientation for a specific joint, were assessed as root-mean-square error (RMSE) between the AHRS orientation quaternion and the orientation quaternion of the gold standard. Results: Analysis of the TUG trials in MC showed a mean RMSE varying between 4.1° and 15.6° for AC, depending on the segment tracked. Along PP, the magnetic perturbation induced at the floor level created an effect limited to the shank (MC: 4.1°; PP 8.2°; p<0.001). However, the accuracy of all lower-limbs joint kinematics was significantly affected by that change in environment (Hip: MC 2.7°, PP 4.7°, p<0.001; Knee: MC 4.5°, PP 9.1°, p<0.001; Ankle: MC 20.4°, PP 25.9°, p=0.006). Analysis of the impact of angular velocity on accuracy revealed that accuracy is worst when mean angular velocity is 30°/s or less. There was also an observed tendency for RMSE to increase when mean angular velocity surpasses 90°/s for a specific task. Conclusion: The current study highlights the impact of environment and type of motion on AHRS orientation accuracy data. Fusion algorithm seems to be optimized for motions with mean angular velocities between 30°/s and 90°/s, performed in an environment with comparable magnetic perturbations between AHRS. However, it



is not always possible to control the environment, and the angular velocity profiles differ a lot between tasks and even between segments within a task. Therefore, tuning of the fusion algorithm should be addressed for AHRS to reach their full potential for clinical evaluation of biomechanics.

O.7.8 Muscle force prediction of the lower limb compared to surface EMG at different walking speeds in individual healthy subjects

Ursula Trinler¹, Richard Baker¹, Richard Jones¹, Kristen Hollands¹

¹University of Salford

BACKGROUND AND AIM: Recent developments in modelling have made it easier to use muscle force predictions to augment clinical gait analysis and enhance clinical decision making. OpenSim [1] claims to provide a straight forward, standardised pipeline (SimTrack) to predict muscle forces that can be implemented in routine processing. This project aims to test SimTrack's potential in the context of clinical gait analysis. The first requirement is to develop normative reference data using a standardised protocol. This protocol will be tested by comparing predicted muscle activations and forces with surface EMG at a range of walking speeds and to analyse speed dependent changes in model parameters and surface EMG. **METHODS:** 10 healthy participants walked at 3 different speeds (comfortable speed, $\pm 20\%$). Kinematics, kinetics and surface EMG of the lower limb were captured (VICON, 4 KISTLER force plates, NORAXON). OpenSim's musculoskeletal model gait2392 was used with its default settings. Joint angles and ground reaction forces serve as inputs to predict muscle activations and forces using computed muscle control (CMC) within SimTrack [2]. Predicted muscle activations were then compared with surface EMG to validate the model outputs. **RESULTS:** The extent of agreement between muscle force predictions and surface EMG varies between muscles (figure 1). For vastus lateralis, for example, model predictions are in general agreement with EMG signals and show similar variation with changes in speed, although the observed EMG peak is slightly earlier in time than CMC excitations and forces at self-selected speed. In contrast, a few muscles, especially tibialis anterior and semitendinosus, show large and unexplained differences between CMC outputs and observed EMG. Semitendinosus, for example, shows peak EMG occurring in late swing, whereas CMC predicts peak muscle activation in mid/late stance. **DISCUSSION:** These results suggest that this protocol including CMC with the default model2392 is running in general. For most walking speeds, muscle forces with CMC can be predicted within a timeframe appropriate for clinical purposes. However using the default settings, the model predictions do not agree with EMG measurements for some muscles important for walking (tibialis anterior, semitendinosus). Furthermore, during pilot testing of quicker walking speeds (up to 40%) CMC crashed and could not be run successfully. Error messages reported that the muscles seem to be too weak. These findings suggest the need of either different generic parameters or subject specific parameters to obtain valid results. Work is continuing to identify which are required to provide more realistic muscle activation and force predictions. 1 Delp (2007) IEEE Trans Biomed Eng, 54(11), 1940-1950. 2 Thelen (2003) J Biomech, 36(3): 321-328.



O.8.1 Relationship between postural sway and motion sickness in young and older adults during a simulated driving task

Alison Novak¹, Behrang Keshavarz¹, Lawrence Hettinger², Thomas Stoffregen³, Jennifer Campos¹

¹Toronto Rehabilitation Institute, ²Liberty Mutual Research Institute, ³University of Minnesota

Background & Aim: Driving simulators are increasingly used for performance assessment, rehabilitation, and training. Unfortunately, visually-induced motion sickness (VIMS) is a common side-effect, especially in older adults. Loss of postural stability has been discussed as a cause of VIMS. The purpose of the current study was to evaluate (1) whether VIMS can be reduced through passive restraint (limiting head and torso movements) during a driving task and (2) whether age affects the occurrence of VIMS and the relationship with balance control. Methods: Twenty-one healthy young (age: M = 25, SD = 6) and 16 healthy older adults (age: M = 71, SD = 6) participated in 2 driving sessions in a virtual environment. The participants' head and torso were either (1) restrained (fixed to a backrest) or (2) unrestrained (no support given to stabilize posture, backrest removed) during driving, with the testing order randomized between subjects. VIMS was measured using a 20-point verbal rating scale (0 = no sickness; 20 = severe sickness). The driving task was performed until moderate VIMS (≥ 10) was reported, or the maximum of 25 minutes of driving was reached. A single force plate (AMTI) was used to assess measures of postural sway (Center of Pressure, COP) during quiet standing before and immediately after each driving session, under eyes-open and eyes-closed conditions. Data were collected at a sampling frequency of 100 Hz, filtered using a 2nd-order Butterworth filter (cutoff-frequency = 6Hz). Linear mixed models and repeated measures ANOVAs were used for data analyses. Results: Older adults showed more sway than younger adults, both before and after the driving test, as shown by significantly greater COP path length ($p = .005$). However, no age-related differences in VIMS scores were seen ($p = .852$). 44% of the older and 57% of the younger adults reported moderate or greater VIMS when driving during the unrestrained condition. However, for these participants, the restrained condition did show a significant reduction in VIMS ($p = .002$). COP measures mirrored this finding, revealing increased postural sway after driving in the unrestrained condition ($p = .039$). After driving, medium to moderate positive correlations between VIMS severity and COP were seen during eyes-closed stance, suggesting that more severe VIMS was followed by greater postural sway. Conclusion: Our results demonstrated that supporting postural stability through passive restraint of the head and torso can significantly reduce the severity (but not fully prevent the occurrence) of VIMS. Although older adults tend to have more postural sway, they are not necessarily more susceptible to VIMS. In our virtual environment the benefits of passive restraint did not differ between older and younger adults. The current results have implications for the design and use of driving simulators, highlighting the importance of postural control to reduce the severity of motion sickness.

O.8.3 Further Study on Otolith Function and Head Stability During Gait

Kazuo Ishikawa¹, Eigo Omi¹, Yoshiaki Itasaka¹, Ko Koizumi¹

¹Akita Graduate School of Medicine



Background and aim: Peripheral vestibular end organ play an important role for postural and gait stability. However it has not yet been fully elucidated on how each organ can affect gait control system, especially toward head stability during gait. Now newly introduced tests to examine the function of otolith organ such as cVEMP and oVEMP have made it possible to examine their function (utriculus function and sacculus function) separately. Our aim for the present study is to elucidate how the otolith organ could affect the head stability during gait in cases with acoustic neuroma which cause various functional abnormality of otolith organs. Method: Twenty unilateral acoustic neuroma patients and nine age and height matched healthy control subjects were enrolled in this study. Subjects were asked to walk freely with comfortable pace with eyes open and eyes closed at a distance of about four meters. Three dimensional movement analysis was performed during gait. .In this study, the analysis was mainly targeted on head movement and peripheral vestibular function. Functional status of the otolith organ was evaluated by cVEMP & oVEMP tests. Results: In AT cases, three cases had normal cVEMP and oVEMP, five cases had abnormal cVEMP with normal oVEMP, three cases had normal cVEMP with abnormal oVEMP, and nine cases had abnormal in both cVEMP and oVEMP. Regarding the relation between those findings and head movement during gait, AT cases had greater horizontal movement, especially in cases with oVEMP abnormality. On the other hand, AT cases with cVEMP abnormality had greater pitch and roll plane movements than that of the control, especially with eyes closed. AT cases with oVEMP and cVEMP abnormality had greater head movement in horizontal, pitch and roll plane. No significant change was found in yaw plane head movement during gait. No significant change was obtained in AT cases with normal oVEMP and cVEMP. Conclusion: Thus otolith function plays some role in stabilizing head during gait, and each organ might have a different contribution between utricles and saccules.

0.8.4 Neuromodulation of the sense of upright to improve dynamic balance after stroke

Dominic Pérennou¹, Valérie Chauvineau¹, Jean-Paul Micallef², Charles Benaim³, Julien Barra⁴

¹Academic Hospital Grenoble, ²Inserm, Montpellier, ³Department of Rehabilitation, ⁴Université Paris Descartes, France

Background and aim A biased verticality perception is one of the major determinant of postural disorders after stroke (Pérennou et al Brain 2008). The main objective of the present study was to investigate the possibility to improve dynamic balance by improving verticality perception, biased after stroke. Here we used the well-known powerful effect of lateral body tilt on verticality perception (Barra et al Brain 2010; Neuropsychologia 2012) Methods Participants- Twelve control subjects and 18 subjects with hemisphere stroke. Baseline- The postural vertical (PV) was $0.1 \pm 0.7^\circ$ in controls and $-3.6 \pm 3.7^\circ$ in strokes. Eight/18 patients presented a contralateral bias of PV ($-7.1 \pm 2.4^\circ$), related to the severity of lateropulsion ($r=0.78$; $p<0.0001$). First experiment- subjects were tilted to one side (ipsilesional or contralesional) at 30° for 10 minutes in the dark. Then PV was measured again. Second experiment- Same experimental setting as in experiment 1 for tilting subjects. Dynamic balance in the frontal plane was investigated using the "rocking platform paradigm" (Pérennou et al, 1998), before and after the modulation of the postural vertical. This task investigates both postural orientation and stabilisation. The kinematics of the support oscillations reflecting the subject's orientation and instability were



measured by an inclinometer fixed under the platform. The degree of the support orientation with respect to horizontal was also strongly correlated with the severity of the lateropulsion. Results First experiment - A strong modulation of the PV was induced in the direction of the initial body tilt. In normals, the magnitude of this modulation was: left ($t(11)=4.2^\circ$; $p<0.002$) and right ($t(11)=-6.6^\circ$; $p<0.0001$). In patients PV was normalised after ipsilesional body tilts ($0.7\pm 7^\circ$; $p<0.001$). Second experiment- Aborted trials were less frequent after 10 mn of ipsilesional body in patients. A two-way analysis of variance (ANOVA) bearing on subjects' groups (patients; controls) and the experimental conditions (baseline condition or after lateral body tilt) revealed a group effect ($F(1, 22)=4.6$; $p<0.05$; $\eta^2=18$), an experimental conditions effect ($F(1,22)=33.8$; $p<0.001$; $\eta^2=61$) and an interaction between these factors ($F(1,22)=15.9$; $p<0.001$; $\eta^2=42$). The post-hoc analysis revealed that the orientation of the trunk (supporting surface) of the controls and patients were different in baseline condition ($-0.44^\circ\pm 0.89$; $-3.2^\circ\pm 2.8$; $p<0.001$) but not different after the lateral body tilt ($0.12^\circ\pm 1.1$; $-0.1^\circ\pm 2.0$; $p=0.98$). No changes was observed on the postural stabilisation index (amount of sway). Conclusion In stroke patients showing lateropulsion due to a biased internal model of verticality, an appropriate modulation of the sense of upright improves dynamic balance by improving verticality perception, and reduces the severity of the lateropulsion. Beyond its clinical interest, this study demonstrates the close link between perception and action.

O.8.5 Wearable sensor-based balance training in older cancer patients with chemotherapy-induced peripheral neuropathy: a randomized controlled trial

Michael Schwenk¹, Linda Garland², Gurtej Grewal², Dustin Holloway², Amy Muchna², Bijan Najafi²

¹Robert-Bosch Hospital, ²University of Arizona

BACKGROUND AND AIM: Chemotherapy-induced peripheral neuropathy (CIPN) can affect lower extremity joint proprioception leading to balance deficits and increased fall risk. This study was aimed to evaluate the effect of a sensor-based exercise program on improving postural control in older adult patients with CIPN. **METHODS:** Twenty two cancer patients (Age 70.3 ± 8.7 years) with objectively confirmed CIPN (vibration perception threshold test score >25 Volt, VPT: $49.6 \pm 26.7V$) were randomized to 4 weeks (twice a week) of sensor-based training including weight shifting and virtual obstacle crossing with real-time visual feedback of lower-extremities through wearable wireless sensors (intervention group, IG, $n=11$) or no intervention (control group, CG, $n=11$). Outcome measures included changes in sway of ankle, hip, and center of mass (CoM) in both medio-lateral (ML) and anterior-posterior (AP) directions during standing in feet closed (FC) position (both feet next to each other) and in semi-tandem position (big toe of one by arch of the other foot), at baseline and post-intervention. Additionally, gait speed and gait variability were assessed. All assessments were made using validated wearable sensors. **RESULTS:** Post intervention, sway of hip, ankle and CoM (ML) were significantly reduced in the IG compared to the CG during FC position ($p=.010-.022$). During the more challenging position of semi-tandem, all sway parameters except ankle were reduced significantly ($p=.008-.039$). Effect sizes were moderate-large ($\eta^2=.255-.388$). No effects were found for gait parameters. **CONCLUSIONS:** To our knowledge, this is the first randomized controlled study demonstrating improvements in balance among CIPN patients from wearable sensor-based training. We speculate that the sensor-based training



with real-time visual joint position feedback provided participants with enhanced information about joint movements and motor error in order to compensate for deteriorated/lost lower extremity joint proprioception from CIPN. We envisage that regular sensor-based balance training in a home-setting may decrease fall risk and thus improve cancer patients' quality of life.

O.8.6 Effects of implantable peroneal nerve stimulation on energy expenditure, gait quality, participation and user satisfaction in patients with post-stroke drop foot using an ankle-foot orthosis

Frank Berenpas¹, Sven Schiemanck², Roos Swigchem¹, Pepijn Munckhof², Anita Beelen³, Frans Nollet³, Alexander Geurts¹

¹Radboudumc Nijmegen, ²Academic Medical Center Amsterdam, ³Amsterdam Medical Center Amsterdam

BACKGROUND AND AIM: Approximately 15% of stroke survivors suffer from contralesional 'drop foot', which is commonly treated with an ankle-foot orthosis (AFO). However, an AFO might limit utilization of residual ankle plantarflexion power during late stance with detrimental effects on leg propulsion and, consequently, gait symmetry and metabolic cost of walking. Functional electrical stimulation (FES) is an alternative for the AFO, as it provides dorsiflexion in swing and enables the use of residual plantarflexion in late stance. Implanted FES is believed to be superior to surface-based FES as it applies a more precise stimulation to the peroneal nerve and problems such as skin irritation are avoided. In this study we investigated the surplus effects of the ActiGait® system (implantable 4-channel stimulator) relative to AFO with regard to energy expenditure, gait quality, participation and user satisfaction. **METHODS:** The ActiGait system was implanted in 11 chronic phase stroke survivors. The timeline of the study is presented in figure 1. Metabolic cost of walking (energy expenditure) during a 6-minute walking test was investigated 3 times; at baseline (using AFO only) and 8 and 26 weeks after activation (FES only). Gait quality was assessed using instrumented gait analysis while walking on a 10m walkway. Spatiotemporal, kinematic- and kinetic characteristics at comfortable speed were obtained 4 times; baseline (AFO) and 2, 8 and 26 weeks after system activation (both AFO and FES). Finally, level of participation and user satisfaction were assessed at baseline (AFO) and 26 weeks after system activation (FES). We also investigated the associations between changes in energy expenditure, gait quality and user satisfaction. **RESULTS:** Energy expenditure during comfortable walking was not different between both devices. Compared to the AFO, walking with FES yielded significantly greater peak paretic plantarflexion angles ($\Delta 4.2^\circ$, $p < 0.05$) and powers ($\Delta 0.5$ W/kg, $p < 0.05$), as well as lower spatial asymmetry ($\Delta 6.3\%$, $p < 0.01$). User satisfaction was greater for FES in all items and 56% of the questioned items was scored significantly better for FES ($p < 0.05$). Reduced energy expenditure was significantly associated with improved walking speed ($r = -0.07$, $p < 0.05$) and increased paretic plantarflexion power ($r = -0.07$, $p < 0.05$). There were no significant correlations between changes in user satisfaction and changes in objective gait parameters. **CONCLUSIONS:** The results of this study indicate that the surplus value of implantable peroneal FES, in comparison to an AFO, indeed appears to be due to better use of residual paretic ankle plantarflexion power during push-off, resulting in more symmetrical gait. Hence, implantable peroneal FES seems most suitable for patients with sufficient ankle plantarflexion.



O.8.7 STANDING SLOWS THE PRODUCTION OF GAZE SHIFTS TO DOUBLE-STEP PERTURBATIONS IN THE ELDERLY.

Paul Stapley¹, Sergio Jimenez¹, Joel Walsh¹, Juno Kim², Maria Markoulli², Mark Hollands³, Alexander Stamenkovic¹, Stephen Palmisano¹

¹University of Wollongong, ²University of New South Wales, ³Liverpool John Moores University

Background and aim: When a sole light cue is presented in the visual field, gaze automatically orients to the target. The illumination of a second light target during this response induces another gaze shift, involving the correction of the initial reactive response. When seated, both types of saccadic eye-movements are delayed in the elderly, compared to the young. Moreover, the nature and timing of eye movements is influenced by postural context in the elderly (Young and Hollands, 2012). Whether a greater delay during gaze shifts occurs when standing compared to sitting in the elderly is however, unknown. The aim of this study was to investigate (for the first time) whether quantitatively different saccadic eye movements occur when the elderly are standing as opposed to sitting. Methods: Ten 18-35 year olds and 10 healthy elderly >65 year old adults participated. All were free of any neurological, vestibular or orthopedic impairment. Two targets were presented to the right (+15°) or left (-15°) of a central fixation point at shoulder height and a distance of 130% arm length. Two types of trial were presented: 1) single step (SS) trials, involving the illumination of either the +15° or -15° target, and 2) double step (DS) trials, in which a second target was illuminated 200ms after the initial (SS) (the first target was extinguished). Therefore, trials from 4 conditions were randomly presented. Each participant executed trials sitting (SIT) and standing (STAND) with targets placed in the same position (height and distance). Participants were counterbalanced: half started seated and the other half, standing. Eye position was recorded at 1,000Hz using electrooculography, synchronised with target onset. Results: 2029 trials were collected. Mean latencies of SS/SIT eye shifts were 199 ±74 ms (young) and 228.3 ±106.6 ms (elderly), and for SS/STAND; 199.9 ±84.5 ms (young) and 218.8 ±107.6 ms (elderly). The elderly's SS gaze responses were statistically the same latency as the young, regardless of postural configuration. 740 DS trials, in which the latency of the initial SS shift >200ms, were retained for analysis. Latencies of DS/SIT trials were 295 ±92.7 ms (young) and 357 ±131.3 ms (elderly), and for DS/STAND were 292.2 ±82.4 ms (young) and 389.7 ±116.3 ms (elderly). Thus, the elderly produced significantly longer secondary gaze shifts during standing compared to sitting ($p < 0.01$), while the young showed no differences. Conclusions: Initial gaze responses towards a single-step visual target were similarly delayed for the elderly (relative to the young) irrespective of whether they sitting or standing. However, the standing posture was found to significantly slow the elderly's ability to shift their gaze towards a new target while no effect was seen in the young. This may be due to the elderly's need to attribute a greater attentional focus to maintaining balance.



O.8.8 Recovery rates of balance control during stance and gait tests after an acute unilateral peripheral vestibular deficit.

John Allum¹, Flurin Honegger¹

¹University Hospital Basel

Background: Acute unilateral peripheral vestibular deficit (aUPVD) patients have balance deficits that improve after several weeks. Determining differences in vestibule-spinal reflexes (VSR) and vestibular ocular reflexes (VOR) with peripheral recovery and central compensation provides insights into CNS plasticity. Also, clinically, knowing when balance control is approximately normal again should guide decisions about working ability. Usually VOR measures are used, despite a lack of knowledge about correlations with balance control. For these reasons, we examined recovery time courses of VSR measures and if these measures correlate with VOR measures. Methods: 25 patients were examined at onset of aUPVD, 3, 6 and 12 weeks later. To measure balance control and therefore VSR function during stance and gait, body-worn gyroscopes mounted at lumbar 1-3 recorded the angular velocity of the lower trunk in the roll (lateral) and pitch (anterior-posterior) directions. These signals were integrated to yield angle deviations. To measure VOR function, rotating chair (ROT) tests were performed with triangular velocity profiles of acceleration $20^\circ/s^2$ and $5^\circ/s^2$, and caloric tests with bithermal (44 and $30^\circ C$) water irrigation of the external auditory meatus. Changes in mean VSR and VOR measures at the 4 examination time points were modelled with exponential decays. Recover was assumed when model values were to within 10% of steady state. Results: All patients had pathological stance and gait test results at aUPVD onset. Balance recovery rates were task and direction dependent. Stance balance improved similarly in the pitch and roll. Both reached steady state at 7.5 weeks. However, visual and proprioceptive influences on stance sway velocities continued to decrease in favour of vestibular influences for ca. 12 weeks. The visual influence was correlated with ROT deficit side responses ($R=0.475$). Spontaneous nystagmus and stance roll velocity were weakly correlated ($R=0.24$). Pitch velocity during various gait tests improved faster than roll. Gait speed was slower and only recovered normal velocity at 6-9 weeks. Pitch velocity when walking eyes closed was correlated ($R=0.38$) with ROT asymmetry. Other VSR and VOR measures were more weakly correlated ($R<0.2$) even if these had similar recovery rates. Results for gait and stance tests were not correlated ($R<0.2$). Conclusions: These results indicate that balance control for stance improves equally fast in the pitch and roll. For gait, pitch control improves faster than roll. On average, stance and gait tests show normal balance control at 6-9 weeks post aUPVD onset. As VSR measures are not strongly correlated with VOR measures, VOR tests should not be used to assess recovery of balance control. The lack of strong correlations between VSR and VOR measures during recovery and compensation of aUPVD supports the hypothesis that recovery of function after aUPVD involves different CNS pathways and neural plasticity mechanisms.



O.9.1 What you see is what you step: The horizontal-vertical illusion increases toe clearance in older adults during stair ascent

Richard Foster¹, David Whitaker², Andy Scally², John Buckley², David Elliott²

¹Nottingham Trent University, ²University of Bradford

BACKGROUND AND AIM: Falls on steps and stairs are a significant cause of morbidity and mortality in elderly people [1, 2]. A simple safety strategy to avoid tripping on steps and stairs is increasing foot clearance. In this study, we determined whether a horizontal-vertical (HV) illusion superimposed on to a surface edge/stair riser to create an illusory perceived increase in surface/riser height would cause older participants to increase their foot clearance. We also determined the optimum parameters for the illusion and whether there was any postural instability caused by the different perceptions of surface/riser height provided by the visual and somatosensory systems. **METHODS:** In Experiment 1 eleven older adults (mean age \pm 1SD, 69.8 \pm 7.3 years) ascended a raised surface with a plain appearance, a high-contrast edge highlighter positioned flush with the tread edge, or vertical black and white square wave gratings of varying spatial frequency (4, 12, 20 cycles per step) superimposed on to the surface riser (which created a HV illusion [3]). In a second experiment fourteen older adults (mean age \pm 1SD, 68.5 \pm 7.4 years) ascended a 3-step staircase with the optimised version of the HV illusion determined in experiment 1 positioned either on the bottom stair riser only, top stair riser only or on the bottom and top stair riser simultaneously. These were compared to a control condition which had plain risers and high-contrast edge highlighters positioned flush with each stair tread edge. Foot placement/clearance and measures of postural stability were compared across conditions. **RESULTS:** In Experiment 1, foot clearance was significantly higher over the surface edge for each spatial frequency compared to plain ($p < 0.001$) or just the edge highlighter present ($p \leq 0.004$). There were no significant differences in foot clearance between spatial frequency conditions ($p \geq 0.64$) but clearance variability was appreciably lower for the 12 cycles per step condition. In Experiment 2, an illusion with spatial frequency of 12 cycles per step on either or both the bottom and top stair risers led to a significant increase in foot clearance over the respective step edge, compared to the control condition (by approximately 17.5%). There were no significant deleterious effects on postural stability. **CONCLUSIONS:** The presence of the HV visual illusion led to significant increases in foot clearance in older adults when ascending a raised surface or staircase, but the effects did not destabilise their postural stability. Inclusion of the HV illusion on raised surfaces (e.g. curbs) or the bottom and top riser of staircases could improve stair ascent safety in older adults. **REFS:** [1] Templer. Cambridge: MIT Press; 1992, [2] Startzell et al. J Am Geriatr Soc. 48(5):567-80, 2000. [3] Elliott et al. PLoS One. 4(2):e4577, 2009

O.9.2 Gazing into thin air: dual-task costs of movement planning and execution during adaptive gait

Toby Ellmers¹, Adam Cocks¹, Mark Williams¹, Will Young¹

¹Brunel University, UK

BACKGROUND AND AIM: In order to avoid hazards we must use visual information in both a feedforward and online manner to plan and guide our stepping actions. When required to negotiate a



series of stepping constraints, older adults (OA) deemed to be at a high-risk of falling will preview the initial constraint for longer durations and more often, and subsequent constraints for shorter durations (Young et al., 2012). Failing to preview subsequent constraints will likely compromise the generation of a visual spatial map and subsequent planning of stepping. Indeed, high-risk OA look away from an initial target earlier in order to fixate future constraints (presumably because they failed to gather this information beforehand); a finding that is causally related to increased stepping errors (Young & Hollands, 2010; 2012). As a result, there is an urgent need to identify the cause of these maladaptive visual behaviours. One suggestion is that OA will not preview areas of their intended path due to inefficiencies in their attentional processing (Young & Williams, 2014). However, to our knowledge there has been no attempt to quantify changes in visual search behaviour during an adaptive gait task under varying degrees of cognitive load. This was the aim of the present research. **METHODS:** Ten young adults walked over a grid of 30 solid black and white wooden blocks (stepping surface 400mm²). White blocks were arranged in one of four non-linear paths running from one side of the grid to the other. Participants were instructed to traverse the path without stepping on the black blocks. Two white blocks were marked with an 'X' ('target blocks'). Participants completed the walking protocol under two conditions: baseline and a serial subtraction dual-task (high, medium and low difficulty). Gait parameters were measured using a 3D motion capture system (MotionAnalysis, USA). Participants completed the walking protocol whilst wearing a head mounted gaze tracker (ASL MobileEye XG) allowing us to quantify visual search behaviours and eye-stepping interactions. **RESULTS:** During conditions of increased cognitive load, participants reduced the number and duration of visual fixations on blocks subsequent to the upcoming target. Further, participants increased the duration of fixations on areas away from the walkway (i.e., fixating task-irrelevant features). The extent to which participants reduced visual search and looked away from the walkway completely were associated with reductions in gait velocity and increased stance time in the targeting limb prior to stepping on to the targets. **CONCLUSIONS:** As predicted, increasing cognitive demands of a second task during adaptive gait had a clear influence on gaze behaviour and stepping performance in young adults. These results suggest that reduced visual previewing observed in high-risk OA may be associated with problems in attentional processing. Further work is necessary to establish these proposed links.

O.9.3 Reduced functional limits of stability during lateral balance perturbations in older adult non-fallers and fallers

Masahiro Fujimoto¹, Woei-Nan Bair², Mark Rogers²

¹Ritsumeikan University, ²University of Maryland School of Medicine

BACKGROUND AND AIM: An impaired ability to control lateral balance contributes to falls in older adults. When standing balance is disturbed, the body center of mass (COM) needs to be regulated in relation to the center of pressure (COP) to ensure postural stability. Since the base of support (BOS) provides a possible area for COP movement, the BOS boundaries have been considered as stability limits within which balance is maintained by rapidly moving the COP to keep the COM from going outside the BOS. Therefore, how "fast" and how "far" the COP moves with respect to the BOS is importantly involved with dynamic balance control. This study investigated the COP position and velocity prior to



first step lift-off (FSLO) during protective stepping for balance recovery in response to lateral perturbations in older non-fallers and fallers. **METHODS:** Thirty-eight Non-Fallers and sixteen Fallers received lateral waist-pulls at 5 different intensities in the left and right directions (L and R pulls). Fall status was identified by the presence of 1 or more falls in the year prior to testing. Crossover stepping responses at the intensity level where the largest number of subjects responded with crossover steps were analyzed. COM and COP positions in the medio-lateral (ML) direction with respect to the base of support (BOS), and COP velocity were calculated. An inverted pendulum model was used to define the BOS lateral stability boundary at FSLO, which was also adjusted using the COP position at FSLO (functional boundary). **RESULTS:** No significant differences were found in the COP velocities between Fallers and Non-Fallers ($p > .093$). However, the COP positions for Fallers were located significantly more medial at FSLO ($p \leq .01$, Fig.1), suggesting that the area functionally used for COP movement was significantly reduced for Fallers in the ML direction. Although the stability margins, measures of stability based on the BOS, were significantly larger than zero for Fallers ($p \leq .004$), they were not significantly different from zero for the functional boundary, i.e., reaching the functional stability limit (Fig.2). **CONCLUSIONS:** COP position with respect to the BOS at FSLO for Fallers was located more medial to that for Non-Fallers, indicating reduced functional limits of dynamic stability. The findings implied that even when the COM motion state for Fallers is located farther from the BOS boundary than for Non-Fallers, ensuring a greater stability margin in relation to their BOS, it is possible that they have approached their functional limit for COP movement. Thus, the functional limit might represent a more sensitive estimation of lateral balance stability. The reduced functional limits of stability for Fallers would predispose them to more precarious stability conditions than Non-Fallers, which could be a cause for taking more steps than non-fallers for balance recovery.

O.9.4 Reduction in older people's fall risk through home-based exergames targeting balance

Kim Delbaere¹, Yves Gschwind¹, Andreas Ejupi², Sabine Eichberg³, Helios de Rosario⁴, Rainer Wieching⁵, Stephen Lord¹

¹University of New South Wales, ²Austrian Institute of Technology, ³German Sport University Cologne, ⁴University Polytechnic of Valencia, ⁵University of Siegen

Background and aim Previous research has shown that supervised home-based exercise can effectively reduce falls in older people. New approaches using sensor-based motion capture systems integrate traditional exercises into virtual environments. Recent preliminary evidence indicates that video game-based exergames may improve physical and cognitive factors associated with fall risk in older people. In this study, an Information and Communication Technology (ICT)- system was used to deliver a home-based exercise program targeting common fall risk factors. The objectives were to investigate the feasibility of the iStoppFalls ICT-based exergame program in older people at home and its effect on physical and cognitive fall risk factors. **Methods** One hundred fifty-three community-dwelling older people aged 65 years or older participated in an international, multicentre, randomized controlled trial. A portable exergame system consisting of a television, personal computer and Microsoft Kinect sensor was installed in the home of intervention group participants ($n = 78$). Three balance exergames targeting weight shifting, knee bending and stepping were recommended for 120 min/week, and five lower limb



strength exercises for 60 min/week. The control group (n = 75) received an educational booklet about general health recommendations. Physical (e.g. physiological fall risk profile assessment, PPA), cognitive (e.g. Trail Making Test), health (e.g. World Health Organization Disability Assessment Schedule), concern about falling (Iconographical-Falls Efficacy Scale), number of falls (monthly falls calendars), quality of life (e.g. European Quality of Life-5 Dimensions) and psychosocial (e.g. Patient Health Questionnaire) outcomes were assessed at baseline and after 16 weeks of intervention. Results Intervention group participants had a median total exercise duration of 11.7 hours (IQR = 22.0). Fall risk measured by the PPA reduced significantly more in the intervention group compared to the control group ($F_{1,127} = 4.54$, $p = 0.035$). Pre-planned subgroup analyses revealed a significant three-way interaction for PPA between the high-adherence (>90min/week, n = 18, 25.4%), low-adherence (<90min/week, n = 53, 74.6%) and control group ($F_{2,125} = 3.19$, n = 75, $P = 0.044$). Post hoc analysis showed a significant larger effect for fall risk ($p = 0.031$, postural sway ($p = 0.046$), executive functioning ($p = 0.044$), and quality of life (p for trend = 0.052) in high-adherers compared to control group participants. Conclusions The iStoppFalls exergame program appears safe and feasible for use in the homes of community-dwelling older people. Sixteen weeks of exergaming reduced physiological fall risk and showed additional benefits in postural sway, stepping reaction and executive function when performed for at least 90 min per week. However, further research and technical development is required to improve adherence and effectiveness towards fall prevention.

0.9.5 Very fast muscle activations during adjustment of tripping responses

Zrinka Potocanac¹, Jaap van Dieen², Sabine Verschueren¹, Jacques Duysens¹, Mirjam Pijnappels³

¹KU Leuven, ²VU University Amsterdam, ³VU Amsterdam

BACKGROUND AND AIM: Tripping over obstacles is one of the main causes of falls in the elderly [1], who are often unable to take an appropriate recovery step [2, 3]. Therefore, recovery step adjustments might be beneficial for fall prevention. We have previously shown that young adults (YA) manage to adjust foot landing position to avoid stepping on an unwanted surface, even under very challenging conditions (such as after tripping) [4]. It is essential to study how one accomplishes these step adjustments and how fast one can alter the muscle activations. **METHODS:** Sixteen YA walked at their comfortable speed over a walkway equipped with hidden obstacles that could unexpectedly appear to perturb the subject in mid-swing and elicit an elevating strategy [4]. Participants were tripped 10 times in between a random number of normal walking trials; 5 trips included a projection of a forbidden landing zone (FZ, 30x50 cm) at the subject's preferred foot landing position. Participants were instructed to land their recovery foot outside the FZ, if it was shown. For seven subjects (21-30 years, 1 female) who successfully shortened their steps to avoid the FZ in all trials, electromyographic activity of the tripped leg muscles tibialis anterior (TA), rectus femoris (RF), gastrocnemius (GM) and biceps femoris (BF) was analyzed. After subtracting average normal walking activity, a wavelet based functional ANOVA [5] was performed to compare 1) three trips performed at the start of the experiment to 2) five trips with a FZ and 3) two catch trips presented in between trips with a FZ. **RESULTS:** To successfully step outside the FZ, the distance from the center of the foot to the center of the FZ at landing was increased from 0.09 to 0.51 m during trips with a FZ. The adjustment of muscle activity started around 110 ms



after trip onset as suppression of GM activity, followed by facilitation of TA activity around 150 ms after trip onset and longer latency changes in all muscles. Foot landing position was also adjusted during catch trips although no FZ was presented. In these trials, the distance from the center of the foot to the center of the FZ at landing was increased to 0.39 m. This coincided with significant changes in the activity of the fastest responding muscles (TA and GM), corresponding to changes shown during the FZ trials. CONCLUSIONS: YA are able to adjust their foot trajectory during balance recovery following a trip by changing muscle activations at very short latencies, well below what would be expected on the basis of voluntary reaction times (<150 ms). Furthermore, subjects learn to apply these adjusted responses in anticipation and show similar fast muscle activity changes during normal trips presented as catch trials. REFERENCES [1] Robinovitch et al., Lancet, 2013 [2] van Dieën et al., SafetySci, 2005 [3] Cordero, PhD thesis Twente University, 2003 [4] Potocanac et al., ExpBrainRes, 2014 [5] McKay et al., JNeurophysiol, 2013

O.9.6 Fall risk reduction in chronic stroke survivors: Acquisition and retention of reactive adaptation to large-scale slip perturbations

Tanvi Bhatt¹, Prakruti Patel¹

¹University of Illinois at Chicago

BACKGROUND AND AIM: Training-induced plasticity within the central nervous system for recovery of locomotion and intentional balance control is well-documented post-stroke. Given that recent evidence indicates that cortical substrates are involved in modulation of reactive balance control, it remains to be known if people with a cortical insult can demonstrate similar learning for reactive balance control. The purpose of this study was to determine if reactive adaptation to large-scale slip-like perturbations can be acquired and retained in community-dwelling stroke survivors. METHODS: Thirteen community-dwelling stroke adults were exposed to a pre-test slip (forward) perturbation while standing (displacement of 0.28m and acceleration of 16.75 m/s²). Subjects were then given a single training session at a lower level intensity (displacement of 0.41m and acceleration 12.00 m/s²).consisting of a block of 8 slip perturbations three wash out walk trials and another block of 3 slips. An immediate post-test consisting of a single perturbation as the pre-test was performed. A retention test was also performed as the pre-test intensity 3-weeks later. Kinematic data was recorded using a passive marker system and EMG from bilateral tibialis anterior muscles recorded via wireless sensors. Center of mass state (its position and velocity) stability (shortest distance to the computational threshold for backward balance loss) and vertical limb support (change in hip height) were computed and analyzed. The reaction time (EMG onset), compensatory step characteristics (step initiation time and backward step length) and trunk angle were also analyzed. RESULTS: There was a significant training-induced linear improvement in postural stability and limb support from 1st to the 11th trial (p<0.01) resulting predominantly from an increase in compensatory step length and decrease in trunk extension (p<0.05). This led to a significant reduction in falls from 100% on the first to 20% on the last trial. There was an inverse relationship between compensatory step length and trunk angle, with increasing backward step length associated with a decrease in trunk extension (p<0.05 for all variables). Compared to the pre-test trial the subjects demonstrated significant improvements on all variables on the immediate post-test



($p < 0.05$) that were maintained at the 3-week post-test ($p < 0.05$). **CONCLUSIONS:** The results show an intact ability of acquiring reactive adaptation post-stroke upon exposure to threatening external perturbations for reducing fall-risk. The significant change demonstrated on the post-test conducted at a different intensity than the training, lends evidence towards training-induced implicit (trial-error) adaptive learning that could be generalized to a wide range of perturbation profiles. Further the significant retention observed at 3 weeks post training indicates the robustness of such single-session training in inducing longer-term learning within this system.

O.9.7 A comparison of accuracy of fall detection algorithms (threshold-based vs. machine-learning) using waist mounted tri-axial accelerometer data

Omar Aziz¹, Edward Park¹, Greg Mori¹, Stephen Robinovitch¹

¹Simon Fraser University

INTRODUCTION: Falls are the leading cause of injury-related hospitalization among older adults. Almost half of those older adults who fall experience a minor injury, and 5-25 percent a more serious injury such as a fracture. Another serious consequence of falls among older adults is 'long-lie' events, where the faller is unable to get up and remains on the ground for an extended period of time. To eliminate long-lies, wearable sensor systems have been developed to automatically detect falls (and alert care providers) based on signals from tri-axial accelerometers. While most systems described to date involve threshold-based algorithms, machine-learning algorithms may offer increased accuracy. The aim of this study is to compare the accuracy of five previously published threshold-based algorithms [1-3] with five machine-learning algorithms on sensor signals collected from a laboratory experiment. **METHODS:** Ten subjects (aged 22-32) participated in trials involving falls, near-falls and Activities of daily living (ADLs). In order to ensure the external validity of our laboratory experiment, the most common causes of falls, observed in a library of video sequences of 227 real-life falls in older adults residing in long-term-care facilities [4], were simulated. The types of falls included: incorrect shift of bodyweight, trip, hit/ bump, collapse/ loss of conscious and slip. Falls due to incorrect shift of bodyweight were further divided into three categories, i.e. imbalance following (i) a misstep or cross-step during walking, (ii) while rising from a chair and (iii) descending from standing to sitting. In addition to the above 7 types of falls, we included 5 types of near-falls and 8 ADLs in our experiment. Data were recorded at 128 Hz, using a single tri-axial accelerometer (ranges of ± 6 g, APDM Inc., Portland, OR) worn on a belt at the anterior aspect of the waist. **RESULTS:** We found that all five machine-learning algorithms provided sensitivities and specificities of at least 90%, while the sensitivities and specificities for the threshold-based algorithms varied from 0% to 100%. Among the five machine-learning algorithms, Support Vector Machine (SVM) provided the highest combination of sensitivity (96%) and specificity (96%) in distinguishing falls from non-falls. Among the threshold-based algorithms, Kangas3phase had the best classification with 94% sensitivity and 94% specificity. **CONCLUSIONS:** Overall, using 3D acceleration data, the machine-learning algorithms performed better than the threshold-based algorithms in distinguishing falls from non-falls with SVM providing the highest sensitivity and specificity of 96%. **ACKNOWLEDGEMENTS:** Supported by AMG-100487 and TIR-103945. **REFERENCES:** [1] Bourke, A. et al. Gait & Posture. 194-9. 2007. [2] Bourke,



A. et al. J Biomech. 3051-7. 2010. [3] Kangas, M. et al. Gait & Posture. 285-91. 2008. [4] Robinovitch, S. et al. Lancet. 47-54. 2013.

O.9.8 Daily-life walking patterns from 1085 days of monitoring in older people with and without a history of falling

Matthew Brodie¹, Stephen Lord¹, Milou Coppens², Janneke Annegarn³, Kim Delbaere¹

¹Neuroscience Research Australia, ²University of Groningen, ³Philips Research Europe

BACKGROUND AND AIM: Fall injuries and morbidity are prevalent in older people and threaten to create a global burden with serious social and economic implications. Walking may provide both exercise and independence and several studies have reported that active older people have fewer falls. However; many falls are caused during transfer movements or walking and some studies have found that increased physical activity, and/or walking only interventions may result in more falls. This suggests further research is required to better understand the trade-offs between increased exposure to falls while walking and health benefits. Furthermore, people may undertake hundreds of walks per day and different to the analysis of repeat walks in controlled clinical settings, it should not be assumed that central values best represent performance, without first investigating how different types of walking are distributed. The objective of this paper was therefore to better understand how walking patterns in older people are distributed during daily-life. **METHODS:** 1085 days of walking data were collected from eighteen independent-living older people (mean age 83 years) using small pendent sensors. Distributions of accelerometer-derived parameters (encompassing gait domains of quantity, exposure, intensity, and quality) were investigated and compared for those with and without a history of falling. **RESULTS:** Day-to-day gait performances varied considerably. Participants completed more short walks relative to long walks, as approximated by a power law. Overall, walks ≤ 13.1 seconds in duration comprised 50% of exposure to walking-related falls. Daily-life cadence was bimodal and step-time variability followed a lognormal distribution. Fallers took significantly fewer steps per walk, had relatively more exposure from short walks, and greater mode of step-time variability. A minimum of one week of monitoring is preferable to reliably assess gait quantity or gait exposure, but three days may be sufficient for assessment of gait intensity or gait quality. **CONCLUSIONS:** Short walks constitute a large proportion of exposure to falls in older people. With respect to gait quality, mode of variability may be a better measure of central tendency than mean of variability to discriminate fallers from non-fallers. The daily-life walking patterns collected remotely over several weeks provide insight into age-related decline in physical functioning and the complex relationships between daily-life walking, exposure, morbidity and falls. **FIGURE CAPTION:** A - Log normal distribution from a non-faller. B - Log normal distribution from a faller. C - Distributions from all participants. Different to clinical gait, the log-normal distribution shows how multiple cumulative factors may negatively impact on daily-life gait. Non-fallers had less variable gait under optimum ambulatory conditions (decreased mode) and more exposure to cumulative factors during daily-life walking (greater skew).