CENTRE OF EXPERIMENTAL MEDICINE

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INSTITUTE OF NORMAL AND PATHOLOGICAL PHYSIOLOGY

8TH INTERNATIONAL POSTURE SYMPOSIUM

SEPTEMBER 9-12, 2018

SMOLENICE CASTLE, SLOVAKIA

ABSTRACTS OF THE 8TH POSTURE SYMPOSIUM

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Smolenice Castle, Slovak Republic, September 9-12, 2018

Editors: František Hlavačka
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SCIENTIFIC PROGRAM

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14:30	Transport by conference shuttle bus from Bratislava to Smolenice Castle
15:30	Registration and accommodation in Smolenice Castle
17:00	Opening Address: doc. RNDr. O. Pecháňová, DrSc. (Slovakia) Director of Centre of Experimental Medicine Slovak Academy of Sciences
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9:15	**Individual differences in intrinsic ankle stiffness and the implications for body sway** [1]T.E. Sakanaka, [2]R.F. Reynolds, [2]M.D. Lakie ([1]Brazil, [2]United Kingdom)
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P9 **Postural stability and its changes of elite young football players during the competition period**
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P10 **Postural stability in children with faulty posture – a pilot study**
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P11 **Functional reach and dynamic balance of healthy 11-year-old children**
K. Kirilova, K. Stambolieva, P. Gatev (Bulgaria)

P12 **Change in body and mind states with stretching exercise improving the posture in school refusal**
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P13 **Gait and balance disorders in patients with PD – detection of specific problematic situations**
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P14 **Gait disorders in patients with generalised dystonia after GPi-DBS: insight from eye movement study**
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ABSTRACTS

VISUAL EFFECTS ON HUMAN RESPONSES TO SUPPORT SURFACE TRANSLATION - OPTIC FLOW MAKES MAJOR CONTRIBUTION

[1]**E. Akcay**, [2]V. Lippi, [3]L. Assländer, [2]T. Mergner

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Introduction

Vision is known to considerably improve human balancing responses to external perturbations by sensory reweighting. Underlying reweighting mechanisms have been described for support surface *tilt* responses by Peterka [1], and a major contribution from vision could be attributed to optic flow (visual velocity) information, which is strongly reduced with stroboscopic illumination [2]. Here we report stroboscopic visual effects on responses to support surface (SS) *translation* for a variety of visual conditions and report first results of an attempt to formally describe important features of the responses using a heuristic model [3].

Methods

Subjects (n = 7) were standing upright on a motion platform that was translated in the body's sagittal plane using a PRTS stimulus (see [1]) with three different peak-to-peak amplitudes (3.5, 7.0, and 10.5 cm). Body sway responses were measured in terms of °/cm and expressed as gain, phase and coherence over frequency. Seven visual conditions were investigated:

Support	Eyes	Visual Scene	Illumination
translation	open	stationary	continuous
translation	open	stationary	stroboscopic
translation	open	moving with SS	continuous
translation	open	moving with SS	stroboscopic
stationary	open	moving	continuous
stationary	open	moving	stroboscopic
translation	closed	-	-

Results

Main findings are: (i) With eyes open and continuous illumination, sway responses showed considerable gain in the low frequency range (where body inertia effects are small). With stroboscopic illumination, gain decreased to low values similar to those obtained with eyes closed. (ii) Continuous illumination had no considerable effect on sway responses when the visual scene was moving en-block with the support surface. (iii) Sway responses evoked by scene motion alone were clearly present with continuous illumination and reduced with stroboscopic illumination. (iv) Constraining hip rotation by a backboard resulted in a reduction of high-frequency response gain and a change in phase behavior, independently of the visual condition.

Conclusions

Similar as in [2] for tilt, visual information improves translation responses mainly by optic flow. The results can be described by a simple model that uses, in addition to vestibular and proprioceptive cues, optic flow information of (a) angular body *position* and (b) linear body *acceleration* for disturbance compensation.

References

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LEG AND CORE MUSCLES' ACTIVITY AFTER LOCAL AND GLOBAL EXCERCISES DURING STANCE

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Introduction

Physiological effects on postural control caused by global and local exercises significantly vary. Both types of exercises contribute to a decrease in the efficiency of using incoming and outgoing signals of the postural system [1,2]. It is known that local muscle fatigue starts the work of inactive muscles and co-activation muscle antagonists as a process of anticipation of postural adaptation. However, there is a lack of information about different global exercises that can decrease postural control. Therefore, the aim of this study was to investigate the effects of exhausting local (toe-lifting) and global (squats) exercises on the postural regulation.

Methods

Physically active young adults (n = 4) 20 - 32 years old performed toe-lifts in 4th series for 35 repetitions with an interval of rest of 3 minutes and squats with a bar using the Smith System, 4 series of 6-8 reps and rest intervals 3 min. Weight of the bar was selected individually according to 80% 1RM. The velocity of the center pressure oscillations (V_{CoP}, $mmsec^{-1}$) and EMG activities of the postural muscles were recorded during quiet standing in a vertical posture before and immediately after both exercises. The EMG activities of the postural muscles and V_{CoP} were recorded during quiet standing in a vertical posture before and immediately after local and global exercises (toe liftings and squats, respectively). Postural testing consisting standing on two legs on an AMTI (100 Hz) dynamometer with open and closed eyes for 30 sec, out under the control of EMG. Wireless surface EMG sensors ("NoraxonDesktopDTS") were attached to the projection of the following leg and body muscles: soleus (Sol), tibialis anterior (TA), gastrocnemius (G), biceps femoris (BF), rectus femoris (RF), rectus abdominis (RA), erector spinae (ES). The duration of each sample was 30 seconds. The interval of 15 sec (middle part of the record) was used for analysis.

Results

During a postural test in physically trained subjects, neither local nor global exercises increased V_{CoP} (ANOVA, $p = 0.281$) and correlated to EMG activities of any muscles. After toe-lifting, V_{CoP} oscillations correlated with activities of TA ($r = 0.69$, $p = 0.058$), RF ($r = 0.88$, $p = 0.004$) and RA ($r = -0.64$, $p = 0.086$). Negative correlation with RA- activities can indicate the compensatory role of abdominal muscles in postural control with fatigue of the calf muscles. The EMG activity of TA, RF and RA, during the postural test hadn't significant changes (all $p > 0.1$) compared to the values recorded before the exercise.After global exercises V_{CoP} oscillations correlated with activities of TA ($r = 0.74$, $p = 0.037$), BF ($r = 0.74$, $p = 0.037$) and G ($r = 0.69$, $p = 0.058$); whereas the relationship with RF ($p = 0.49$) was non-significant. EMG activity of ES was increased ($p = 0.0009$) in comparison with the values in postural tests both before the exercise and after rising to the socks ($p = 0.011$). In addition, EMG activity of BF tended to increase ($p = 0.097$) compared to activity before exercise. Since increased ES activity does not correlate with V_{CoP}, apparently an increase in the activity of the back muscles ensures stabilization of the trunk, and balance maintenance is ensured by the activity of the muscles of the lower extremities (manifestation of the ankle strategy).

Conclusions

Fatigue of postural muscles reduces the ability to regulate the posture, which is reflected by the appearance and intensification of the correlation between the V_{CoP} and the activity of the postural muscles of the legs and trunk, which under normal conditions are low. Fatigue of some postural muscles causes a redistribution of muscle activity, a decrease in their role and, on the contrary, an increase in the activity and role of other muscles in maintaining the postural balance.The change in the correlation between V_{CoP} and the activity of the postural muscles showed that maintaining the body balance during fatigue is provided by a change in the regulatory activity of the postural muscles. The role of fatigued muscles in keeping body balance is reduced. On the contrary, less tired postural muscles are actively involved in the regulation of the balance. At the same time, some muscles of the trunk (for example RA) provide a stabilizing posture, rather than an active role.

References

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[2] Zemková, E. 2014. Sport-specific balance. In *Sports Med*. 2014, vol. 44(5), p. 579-590.

APPLICATION OF CONFIRMATORY FACTOR ANALYSIS TO VERIFY GAIT MODELS IN PEOPLE WITH PARKINSON'S DISEASE

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Introduction

Baropodometric walkways allow to measure a large number of spatial-temporal gait variables. In order to easily analyze gait in healthy subjects (HS), it is advisable to reduce the number of gait variables to be handled. Indeed, models of gait that included from three to five different factors (e.g. "pace", "rhythm", "postural control") were validated through exploratory factor analysis [1-4]. Gait is a strong indicator of health, and poor gait is a predictor of risk of falls and mortality [5]. One of the major functional disabilities in people with Parkinson's disease (PwPD) is gait disorder. However, at variance with HS, there are no agreed standardized protocols for measuring gait in PwPD. The aim of this study was to reduce the number of gait variables in PwPD, identifying the most relevant model describing gait abnormalities. Therefore, we (1) assessed the reliability of all the variables showed by previous models for HS and (2) analyzed the validity of multifactorial models of gait in PwPD.

Methods

The spatial-temporal variables of gait in 250 PwPD were averaged over four trials, in which patients were asked to walk at their usual velocity on the baropodometric walkway. To verify if the four models proposed in HS were applicable in our sample of PwPD, confirmatory factor analysis (CFA) was carried out using the structural equation modelling. To determine test-retest reliability of variables presented in these models, intraclass correlation coefficients (ICC) were used.

Results

None of the four models of gait considered in HS [1-4] achieved the convergence when CFA was performed on data of PwPD. The ICC of gait variables considered presented values between 0.38 and 0.99. Only 15 of this 33 variables achieved values higher than 0.90, that represented good reliability. On the contrary, most of the variables regarding asymmetry and variability, the latter calculated as Standard Deviation (SD) [1,4] or Coefficient of Variation (CV) [2,3], showed poor reliability, with ICC values less than 0.90.

Conclusions

Models of gait considered in HS were not valid for PwPD. The non-convergence of each model could be due to the fact that they included about 25-60% of variables of gait that proved to be not reliable in our sample of PwPD. Based on these findings, we suggest that a new model of gait specific for PwPD could be created after selecting the variables of gait. In particular, this model should contain variables that are (1) reliable and (2) unique, that means each variable can give its contribution to the model without being predicted by the other variables.

References

[1] Verghese, J. - Wang, C. - Lipton, R.B. - Holtzer, R. - Xue, X. 2007. Quantitative gait dysfunction and risk of cognitive decline and dementia. In *Journal of Neurology, Neurosurgery & Psychiatry*. 2007, vol. 78(9), p. 929-935.

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SENSORY INTEGRATION OF LIGHT TOUCH CUES IN HUMAN STANDING BALANCE

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Introduction

In upright stance, sensory information from touching a space stationary reference point reduces spontaneous sway [1]. In addition, body sway responses can be evoked by moving the space reference, where the sway responses show a non-linear pattern that has been dedicated to sensory reweighting [2]. However, integrating sensory cues from a light touch reference requires a comparison to cues encoding angular orientation in space (vestibular) or to the floor (ankle proprioception). Therefore, we hypothesized that light touch cues are transformed to the same reference frame as the vestibular and proprioceptive cues, or vice versa.

Methods

Eight subjects (27 +/- 3 yrs, 4 male) lightly gripped a robotic manipulandum which moved in a circular arc around the ankle joints. A pseudo-randomized motion sequence with broad spectral characteristics was applied 13 consecutive times at three amplitudes. The stimulus was presented at two different heights and therefore different radial distances, which were matched in terms of angular motion. Hip and shoulder sway was measured and whole body centre of mass sway was calculated thereof. Model simulations were performed in Simulink (The Mathworks, Natick, USA) to reproduce sway responses including the hypothesized transformation and the mechanism underlying reweighting.

Results

The stimulus at the larger radial distance evoked a significantly larger body sway response at each of the three stimulus amplitudes. However, plotting sway response amplitudes with respect to horizontal stimulus amplitudes - as opposed to the angular stimulus amplitude – revealed a consistent change of sway responses with respect to changing stimulus amplitudes for all six conditions. Sway responses showed a non-linear pattern, where the ratio of stimulus and sway response decreased with increasing stimulus amplitude. Model simulations were able to reproduce sway responses with a variance accounted for of 94% across all conditions. The proposed model includes an estimation of finger movement in space that includes a coordinate transformation and a threshold element generating the nonlinear effects dedicated to reweighting.

Conclusions

Our results reject the hypothesis that light touch cues are referenced to angular motion around the ankle-joints. Rather, the touch reference seems to be integrated in terms of absolute horizontal movement. To this end, a subjective horizontal (or vertical) is required as a reference frame for the integration of the light touch cues.

The mechanism generating reweighting is reminescent of the Disturbance Estimation and Compensation model proposed by Mergner [3], where - analogous to the finger movement estimation in the presented study - support surface tilts are estimated from sensory cues with a threshold generating sensory reweighting. Thus our results add to the evidence that humans use estimates of external perturbations in the feedback control of upright standing balance.

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GAIT VARIABILITY AND SYMMETRY AND ITS RELATIONSHIP TO THE LOWER LIMB MUSCLE STRENGTH

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Introduction
Deteriorations of balance and lower limb muscle strength are important intrinsic fall-risk and injury-risk factors in all age groups [1]. Measurements in dynamic conditions provide relevant information for injury prevention. The assessment of the relationship between muscle strength and gait has been performed for spatial-temporal gait characteristics [2]. With the increasing popularity of wearable sensors, additional aspects of gait can be studied in relation to lower limb muscle strength. Therefore, the aim of this study was to assess the relationship between lower limb muscle strength and gait variability and symmetry characterized by trunk movement.

Methods
Twenty nine healthy young adults (age: 22.7 ± 2.6 years) participated in this study. Gait was assessed using two sensors Physiolog (GaitUp, Lausanne, Switzerland, sampling rate 128 Hz) attached to the back at the level of L5 vertebra and sternum while walking in a 40 meters-long corridor for 6 minutes at a self-selected stable pace. 3D acceleration was considered for computation of gait variability (root-mean-square, RMS) and symmetry (harmonic ratios). Lower limb strength testing was performed by isokinetic dynamometer IsoMed 2000 (D. & R. Ferstl GmbH, Hemau, Germany) in a reciprocal isokinetic concentric mode of muscle action for plantar and dorsal flexors, ankle invertors and evertors, knee flexors and extensors, hip flexors and extensors, hip abductors and adductors in four repetitions. The maximal isokinetic strength was assessed by maximum peak torque reached throughout repetitions. Pearson correlation coefficients were used for assessment of relationship between muscle strength and gait characteristics.

Results
The relationship between gait characteristics and lower limb muscle strength was statistically significant only for lower trunk gait variability. Significant correlations were found between lower trunk RMS in the anterior-posterior direction and muscle strength of plantar flexors ($r = -0.40$), ankle evertors ($r = -0.46$), knee flexors ($r = -0.54$), knee extensors ($r = -0.50$), hip abductors ($r = -0.40$), hip flexors ($r = -0.57$) and hip extensors ($r = -0.47$). Furthermore, significant correlations were found between lower trunk RMS in the medial-lateral direction and hip adductors ($r = -0.42$).

Conclusions
According to the results of the present study, the lower limb muscle strength influences variability of the lower trunk but has no effect on the upper trunk or gait symmetry computed from the signal of lower trunk.

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DYNAMIC POSTURAL CHANGES IN THE SOLEUS MUSCLE VIBRATION OFFSET DUE TO AGE AND PARKINSON'S DISEASE

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Introduction
Postural instability and falls are major and devastating features of ageing and Parkinson's disease (PD) [1]. The fall risk increases gradually with disease progression [2]. The balance problems and increased incidence of falls has been associated with decreased functional ability to adapt to altered sensory conditions. While changes in balance have been described in many studies under steady-state conditions, less is known about the dynamic changes in balance following sudden transition to different sensory inputs. The aim was to clarify different effects of age and Parkinson's disease on dynamic postural responses immediately after lower leg muscle stimulation offset. Sudden removing of active sensory input represents a transient period in balance control.

Methods
In the study participated 13 healthy young (4 males, 9 females, mean age 25.0 ± 2.3 years), 13 healthy elderly (4 males, 9 females, mean age 70.1 ± 4.5) and 13 PD patients (8 males, 5 females, mean age 63.7 ± 5.7; mean duration of disease 1.9 ± 2.4 years, H&Y scale ≤ 2.5 for the ON phase; motor component of the UPDRS 23.8 ± 7.5 for the ON phase). Postural responses to proprioceptive bilateral vibration of soleus muscles during stance were assessed by a force platform and two accelerometers attached on the upper and the lower trunk. The experimental protocol consisted of 2 conditions of soleus muscle vibration with 1) eyes open and 2) eyes closed randomly repeated four times. The duration of each trial was 20 s; the vibration lasted 8 s with the frequency 60 Hz and amplitude 1 mm. The dynamic responses were quantified by final shift (final position) before vibration offset and four parameters immediately after vibration offset: final backward and forward peak amplitude, peak-to-peak amplitude and maximal velocity.

Results
Our results showed that soleus muscles vibration evoked larger postural responses with increasing age and Parkinson's disease. During vibration period, age-related differences were found in final shift (final position before vibration offset) of trunk tilts. However, the postural responses in elderly and PD patients were similar. Contrary, immediately after vibration offset significantly larger backward amplitude of centre of foot pressure (CoP) displacement and trunk tilts were observed in PD patients compared to healthy peers. In returning to vertical position, peak-to-peak amplitudes, maximal velocity of CoP and trunk tilts significantly increased in PD patients. Without vision, the postural responses of PD were more enhanced. The differences between young and elderly were found in all parameters, especially the

peak-to-peak amplitudes, maximal velocity of CoP and trunk tilts in transient period after vibration offset.

Conclusions

While differences between young and elderly were seen during and after vibration, PD patients were more influenced by the vibration offset. The PD patients showed more unstable transient postural responses to selective sensory stimulation switch off, which may reflect impairment of sensory reweighting in balance control. Analysis of responses not only during the vibration period, but especially in the dynamic transient period immediately after stimulation offset distinguish between age-related physiological changes and actual pathological changes in PD patients. These transient periods of sudden changes from sensory environment could challenge the postural stability of PD patients even in early stages with potential fall risk. Understanding how early stages PD patients differ in balance control from neurologically intact peers may help researchers and clinicians to refine their intervention and fall prevention programs.

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IMPAIRED DYNAMIC STABILITY WHILE TURNING IS A KEY RISK FACTOR FOR FALLS

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Introduction

Difficulty in turning during gait is a common struggle for older adults with balance disorders and/or Parkinson's disease (PD). Relative to linear gait, turning requires more neural resources to properly plan and execute the movement. The main aim of this abstract is to expose a common link between distinct turning-related studies and identify potential for novel neurorehabilitation strategies.

Turning in Parkinson's disease and community-dwelling older adults

Mellone et al. [1] found PD subjects to exhibit speed- and angle-specific impairments in dynamic stability during turning while engaging in a complex locomotor task. The most significant postural instability was observed when subjects were asked to perform 90° turns and when they were asked to walk and turn faster than their preferred speed.
Leach et al. [2] used in-home activity monitoring methods to study the relationship between turning strategies and fall risk in community-dwelling older adults. Recurrent fallers exhibited both lower turn quantity and quality compared to the non-/single fallers. The findings from Mancini et al. [3] support these results and show that 90° turns are the most commonly executed.
Our state-of-the-art, web-based fall-risk assessment tool (FRAT-up [4]), tested on the InChianti cohort, was found to have few associations with turn features. This suggests that certain turning features may serve as independent predictors of future recurrent falls and improve the predictive performance of the tool.

Conclusions

Neurorehabilitation could focus on modifying turning strategies for 90° turns, with an emphasis on scaling turning speeds at different speeds of walking. Assessment tools targeting turning ability should also be adopted (e.g. L Test instrumented with inertial sensors) to determine the efficacy of specific intervention strategies.

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BIOFEEDBACK EFFECTS IN PARKINSON'S DISEASE: MULTIPLE TIME-SCALES ANALYSIS

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Introduction

In this study we investigate the effects of motor adaptation and motor learning in persons with Parkinson's disease during a home-based gait training program built on auditory biofeedback (BF). For this purpose, we assessed the motor response produced immediately after auditory BF messages and analysed it at multiple time-scales in order to quantify: i) motor adaptation in response to BF (Short-term response, *STR*); ii) intra-trial dynamics of motor adaptation (Mid-term response, *MTR*); iii) motor learning through a longitudinal analysis of a 6 weeks home-based gait training program (Long-term response, *LTR*).

Methods

Ten persons with PD undertook gait training with the CuPiD system during a period of 6 weeks [1]. The CuPiD system offered praising/corrective verbal feedback, encouraging to keep the pre-set spatio-temporal gait parameters within the therapeutic window during walking in a daily environment. In this study we shall present the results obtained when stride length was the feedback variable. From the 9 steps following the BF messages, a single-term exponential decay/growth was fitted ($y = \pm M * e^{-k*x}$) in response respectively to the UP ("increase stride length") or DOWN ("decrease stride length") BF messages. Outlying responses were removed by retaining only fitted *k* values in the range (-0.2, 8) step^{-1} aiming to exclude absent or non-physiological responses. Motor adaptation, *STR*, was quantified by the exponential decay/growth factor k estimated during all trials and analyzing its statistical distribution. Next, the relative decay time constant was obtained as $\tau = 1/k$. The intra-trial dynamics of adaptation, *MTR*, was quantified by the slope s_m of the linear trend of *k* throughout each individual trial, in each subject. Motor learning effect, *LTR*, was quantified by the slope s_l of the linear trend of average *STR* responses along the treatment, for each subject.

Results

An overall number of 178 training sessions were performed by the subjects. In particular, a total of 2562 corrective feedback messages were identified, of which 21% had absent or outlying responses. Motor adaptation following BF was well visible in 93% of the analysed trials. Table 1 reports the median value and interquartile range of the BF responses at multiple time-scales. The results indicate that the median value of *k* is 0.23 step^{-1} for the UP and 0.20 step^{-1} for the DOWN messages (i.e. τ of 4.3 and 5 steps, respectively). The results obtained for *MTR* and *LTR* analysis, expressed as a percentage change of *k*, show a very high variability between subjects. Aware of this, *MTR* seems to indicate a faster adaptation along a training session, in particular in response to DOWN messages where the value of *k* increases by about 7.9 % after each message. *LTR* analysis seems to show a positive change in locomotor response immediately after DOWN messages. In fact, k increases by about 5.7 % after each trial, as the potential effect of a new learned skill during the treatment.

Table 1. *STR, MTR and LTR: Statistical analysis of the responses to BF messages at different time-scales.*

Time-scale	***Descriptor***	***DOWN-Messages*** *Median (Q1;Q3)*	***UP-Messages*** *Median (Q1;Q3)*
STR	k [step^{-1}]	0.20 (0.12;0.28)	0.23 (0.19;0.29)
MTR	s_m [%]	7.9 (-71.4;11.4)	-0.3 (-2.5;5.3)
LTR	s_l [%]	5.7 (-3.5;44.7)	0.1 (-6.8;0.8)

Conclusions

Our results indicate a “refractory” period between 5 and 15 steps (3τ) as the time needed to adapt gait pattern and reach 95% of the planned target value following a corrective feedback. For clinicians and BF developers this is informative to know how long to wait until providing BF again. The high variability in *MTR* and *LTR* values suggests that further analyses are needed before drawing conclusions on motor learning in this group.

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THE THROW-AND-CATCH HYPOTHESIS OF HUMAN STEPPING: DEALING WITH VARIABILITY

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We explore goal-directed stepping for reorienting the body or initiating gait. A key issue concerns the control of balance. We argue that standing balance is relinquished while the stepping foot is in the air thus allowing the body to fall under gravity. The falling body's trajectory is largely controlled by motor activity that occurs before the stepping foot leaves the ground (the *throw*), and is finely tuned to where and when the foot is planned to land (the *catch*). Stepping to different positions is accomplished not only by different *throws* but also by different movements of the stepping leg executed on the falling body (the *reach*). This close coupling between the *throw* and *reach* when stepping to different regions of the workspace is paramount for achieving the stepping goal while simultaneously ensuring balance is regained at the end of the step. Nonetheless, even when repeatedly stepping to the same target from an identical starting position, there is inherent variability in both the body trajectory (resulting from the *throw*) and the leg-on-body trajectory (resulting from the *reach*). Theoretically, one might expect these two sources of variation to sum to produce even greater variation of the foot-in-space leading to foot placement inaccuracy. However, we find that this is not the case. The foot placement variation is considerably less than this theoretical value. This is because the two sources of variation are not independent. We show they co-vary such that deviation of the falling body trajectory from its mean path is compensated by an oppositely-directed deviation of the leg-on-body trajectory from its mean path. Surprisingly, this is also true when visual feedback is prevented during the step. Possible mechanisms underlying this fine coordination of the sequential *throw* and *reach* will be discussed.

CERVICAL JOINT HYPOMOBILITY SIMULATED BY NECK BRACES AND CERVICAL ORTHOSIS ALTERS GAIT INITIATION PROCESS

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Introduction

Cervical joint mobility is known to be important for head stabilization during locomotion, allowing the orientation of the visuo-vestibular system [1]. In the present study, we questioned whether cervical joint mobility also plays a role during the quasi-static phase of postural adjustment preparing gait initiation (GI), corresponding to the so-called “anticipatory postural adjustments” (APA) [2]. It is hypothesized that cervical joint hypomobility induced by an orthosis wear will alter APA, with negative consequences on GI motor performance and/or balance.

Methods

Fifteen healthy young adults participated in the study. They performed series of ten gait initiation at a self-paced speed on a force-plate in each of the following conditions randomly assigned: GI (Ctrl), GI with neck bandage, GI with cervical flexible orthosis, GI with cervical rigid orthosis (these three last conditions differed by the rigidity of the neck brace), and a control condition. Classical biomechanical GI variables were analyzed and compared across conditions with repeated measure ANOVA and Tukey *post hoc* tests when necessary.

Results

Results showed none of the GI parameters changed between “flexible cervical orthosis”, “neck bandage” and the “control” condition. In contrast, the amplitude of APA (i.e. backward shift of CoP) was shorter ($p < 0.05$) and the peak of antero-posterior center of mass velocity at the foot-off was lower ($p < 0.05$) in the “rigid cervical orthosis” condition compared to all others conditions. Duration of the execution phase was also significatively enhanced in this condition ($p < 0.05$). The APA duration, the step length and the braking of the vertical center of mass fall during the execution phase - which is an indicator of balance control [3] - did not change across the conditions (Figure 1).

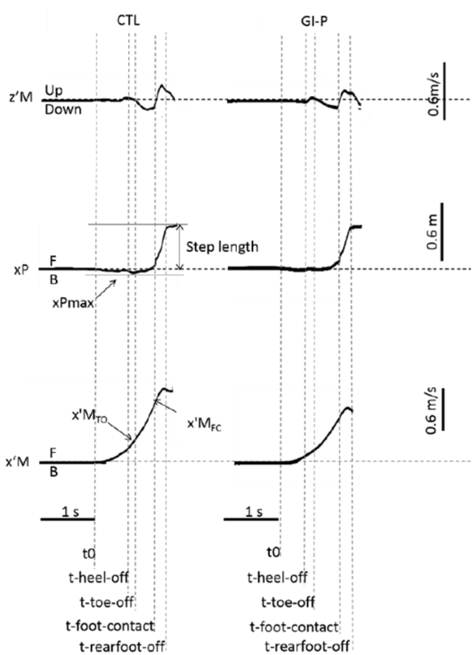

Figure 1. *Typical biomechanical traces in the two experimental conditions (Ctrl and Cervical rigid orthosis). z'M is the CoM velocity along the vertical axis, x'M is the CoM velocity along the antero-posterior axis and x_p is the CoP displacement along the antero-posterior axis. B and F are respectively the backward and the forward directions. Up and Down are respectively the vertical directions. t0, t-heel-off, t-toe-off, t-foot-contact and t-rear-foot-off are respectively the instants of gait initiation onset, swing heel-off, swing toe-off, swing foot-contact and rear foot-off.*

Conclusions

These results showed that the simulation of a cervical joint immobility, herein induced by the rigid orthosis wear, led to a less efficient APA probably due to an alteration of Tibialis anterior electromyographic activity. As a consequence, a lower motor performance was reached during APA. However, during execution phase, motor performance was preserved due to the augmentation of single stance duration. Balance control was also preserved. Cervical mobility therefore seems to be an anatomical parameter that is taken into account in the programming of APA, and immobilizing this joint leads to a more cautious strategy to initiate gait. Cervical joint stiffness with aging or pathology [4] might be a factor contributing to slower GI.

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Adaptation to predictable postural perturbations induced by a mobile platform in patients with Parkinson's disease

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Introduction

When healthy subjects (HS) stand on a platform continuously and predictably moving in an anterior-posterior direction, balance control relies on a progressive adaptation of the activity of the lower limb muscles [1]. At variance with HS, patients with Parkinson's disease (PwPD) show instability when standing on a predictably moving platform [2]. We hypothesized that, under this condition, instability of PwPD is related to impaired adaptation process.

Methods

We recruited 32 PwPD (age 68.7 years ± 6.9; Hoehn-Yahr range 2-2.5) and 14 HS (69.9 years ± 4.5). The participants stood blindfolded on a platform continuously moving 100mm back and forth at 0.4Hz in the horizontal plan for 45 cycles. Area of electromyographic (EMG) responses (as % of maximal voluntary contraction) of Tibialis Anterior (TA) and Soleus (Sol) muscles of both legs was measured during the whole duration of each successive cycle. An index of adaptation (IA) was calculated for each muscle as the ratio of the EMG area averaged across the last six cycles to that averaged across the first six cycles. Kinematics was evaluated through reflecting markers, positioned on lateral malleolus, greater trochanter and head, detected by a stereophotogrammetric system. We then evaluated the standard deviation (SD) of the antero-posterior displacement of the marker on the head and greater trochanter. For each marker, we calculated an index of stability (IS) as the ratio of the SD averaged across the last six cycles to that across the first six cycles.

Results

Area of EMG activity of both TA and Sol muscles in the first cycle of the series of platform displacement cycles was similar in PwPD and HS. In HS, TA activity showed a rapid decrease in the first few cycles. In PwPD, EMG activity decreased to a smaller extent and even increased in Sol. The IA of Sol EMG was about 109% in PwPD and 96% in HS, while the IA of TA EMG was about 100% in PwPD and decreased to about 68% in HS ($P < 0.05$). The IS of the head was 90% in HS and 112% in PwPD ($P < 0.05$); the IS of the greater trochanter showed a similar behavior (96% in HS and 111% in PwPD, $P < 0.05$).

Conclusions

EMG activity of TA muscle adapts during subsequent cycles of platform displacement in HS [3]. This phenomenon is accompanied by reduction of body oscillations [1]. TA muscle appears to play a balance control role: reduction of TA activity in HS decreases ankle muscle co-contraction leading to a reduction of the postural destabilization produced by the platform displacements [1]. On the contrary, the patients' difficulties in adapting to the predictable movements of the platform are shown by both the impaired reduction of EMG activity of the TA muscle and the inability of reducing the destabilization of body segments. In both groups, Sol activity remains constant or even increases in PwPD, in keeping with the notion of a postural role of Sol not only during quiet stance but also during postural perturbations. The impaired adaptation of TA EMG activity to predictable postural perturbations might be related to the known abnormalities in anticipatory postural adjustments in PwPD [4] and can partly explain their postural instability in everyday life.

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POSTURAL STABILITY AND ITS CHANGES OF ELITE YOUNG FOOTBALL PLAYERS DURING THE COMPETITION PERIOD

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Introduction

The main objective of this thesis is to determine the parameters of postural stability at young football players in relation to their age during the football season and eventually clarify any differences among the various age categories and across different player groups [1].

Methods

75 elite football male players in the age categories from 12 to 15 years participated in this study (U12 n = 18; age 11,4 years; height = 148,8 ± 7,4 cm; weight = 38,5 kg ± 5,8 kg; U13 n = 21; age 12,4 years; height = 154,1 ± 5,4 cm; weight = 43,7 kg ± 5,0 kg; U14 n = 16; age 13,4 years; height = 161,1 ± 8,5 cm; weight = 49,9 kg ± 10,1 kg; U15 n = 20; age 14,3 years; height = 170,7 ± 7,8 cm; weight = 55,8 kg ± 7,1 kg). The postural stability at stance was tested by help four tests: stance with opened eyes (SOE), stance with closed eyes (SCE), flamingo test on the right foot (FLR), and flamingo on the left foot (FLL). Postural stability was measured using a Footscan pressure (RScan, Belgium) with frame rate 30 Hz and length of the test 30 s for standing on both lower limbs and 60 s for one lower limb standing. The evaluated parameter was Total Traveled Way (TTW).

Results

There were found some significant differences: TTW (close eyes) Chi-square (62, 3) = 9,80; p < 0,05. Post hoc Kruskal-Wallis Multiple-Comparison Z-Value Test (Dunn's Test) showed significance between U13 a U15 Z-test = 3,07. Category U15 has significant higher values in comparison to U13. TTW (Flamingo): Chi-square (62, 3) = 9,24; p < 0,05. Post hoc Kruskal-Wallis Multiple-Comparison Z-Value Test (Dunn's Test) showed significance between U12 a U15 Z-test = 2,59 a U12 a U14 Z-test = 2,69. Category U12 has significant higher values than U15 and U14. Results before and after the season period (pair t-tests): open eyes (TTW: Z-value = 1,72 p < 0,05; higher values after the season), close eyes (Z value = 3,98 p < 0,001; significantly worst before the season), Flamingo test (TTW-FL-R: Z-value = 1,75 p < 0,05; higher and worst values after the season), (TTW-FL-L: Z-value = 1,90 p < 0,05; higher and worst values after the season).

Conclusions

The results showed that postural stability at both-feet stance is comparable and statistically indifferent among the different age categories. It was also concluded that long-term training and football matches workload within a season has a negative impact on the postural stability of the players. At the end of the testing period (i.e. after concluding the first half of the football season), virtually all parameters in all age categories of the football players worsened.

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POSTURAL CHANGES DURING GAIT INITIATION IN SLIGHTLY OBESE ADULTS

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Introduction

Increased body mass index (BMI) has been linked with an increased risk of a number of significant health issues including musculoskeletal problems. Most locomotion-related falls occur while initiating gait [1]. Previous evaluation of the anticipatory postural adjustments (APAs) in obese subjects was mostly focused on morbidly obese subjects with BMI greater than 35 kg/m^2 [1,2]. Little is known about postural stability and APAs parameters in slightly obese subjects with the BMI lower than 35 kg/m^2. Therefore, the aim of the study was to examine balance control of slightly obese young adults during gait initiation with and without crossing an obstacle.

Methods

Forty-four subjects participated in the study. According to their body mass index values, they were divided into two groups: control (normal weight subject with the BMI lower than 25 kg/m^2: 9 females, mean age 32.2 ± 1.3 years) and slightly obese group (subjects with the BMI from 25 to 35 kg/m^2: 9 females, mean age 32.5 ± 1.3 years). Participants were instructed to initiate gait with their right leg after hearing a sound signal in two conditions: without (GI) and with crossing the obstacle (GIO) situated in front of them. Center of foot pressure (CoP) and kinematics of fifth lumbar vertebra (L5) were evaluated using a force plate and a motion capture system. Two parameters of CoP and L5 in medio-lateral (ML) direction were evaluated: 1) peak to peak amplitude (App) – the amplitude in ML direction between maximal position of CoP/L5 in the swing side (right) and the maximal position of CoP/L5 in the stance side (left); 2) peak to peak velocity (Vpp) – the velocity in ML direction between maximal position of CoP/L5 in the swing side (right) and the maximal position of CoP/L5 in the stance side (left). Repeated measures ANOVA were used to determine the effect of group, obstacle and their interaction on CoP and kinematic (L5) parameters.

Results

Destabilizing effect of higher BMI was observed during the unloading phase of gait initiation with and also without crossing the obstacle. Slightly obese subjects loaded the weight of their body from one leg to another with greater and faster CoP shift represented by increased peak to peak amplitude (App) and velocity (Vpp) compared to normal weight peers. Presence of an obstacle increased amplitude and velocity of the lateral CoP shift similarly in both groups. In contrast to CoP parameters, the kinematic analysis of L5 marker did not show the destabilizing effect of higher BMI on lateral shift of lower trunk during gait initiation.

Conclusions

We have shown that increased CoP parameters values and thus increased postural instability during unloading phase of gait initiation is present not only in morbidly obese, but already in slightly obese subjects with BMI lower than 35 kg/m^2. Absence of BMI-related differences on L5 segment during gait initiation may indicate that postural control was already successfully performed in feet (CoP). It seems that control strategy of slightly obese adults successfully maintained the line of progression within the base of support to avoid imbalance of lower trunk (L5) segment.

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WHY DO WE LOOK WHERE WE ARE GOING? THE ROLES OF EYE MOVEMENTS IN THE CONTROL OF LOCOMOTION

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Although it is unsurprising that pedestrians tend to look where they are going during various forms of locomotion (e.g. in a desired direction in advance of turning or at specific places on the ground that are subsequently stepped on) the nature of the information gained and how it is used by the locomotor control centres within the Central Nervous System remains unresolved. I have spent many years trying to understand the important contribution that eye movements make to the control of locomotor adaptations and the underlying neural mechanisms.

I will give an overview of my recent research findings that demonstrate gaze behaviour during walking and turning forms part of a robust coordinated eye, head and whole body postural synergy. For example a recent study showed that when eye movements are abolished during on the spot turns (by asking participants to fixate on a head-mounted target) that stepping patterns are disrupted; supporting the hypothesis that turns are usually organized as a coordinated whole-body gaze shift [1].

I will also provide evidence that changes to where we look as a function of age, emotional state and neuropathology are causally related to increased risk of trips and falls. For example, anxiety during walking can result in older adults displaying altered gaze behaviour during target stepping that paradoxically results in less accurate and more variable foot placement thereby increasing the risk of future trips and falls [2,3].

Finally, I will present recent findings suggesting that interventions aimed at changing maladaptive gaze behaviour show promise in improving walking safety in frail individuals. For example, simply asking walkers to preview their route for 10s prior to commencement of walking increases self-confidence and significantly improves stepping accuracy and consistency in older adults performing target stepping tasks in the laboratory [4].

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KINEMATICS OF GAIT TERMINATION AND GAIT INITIATION DURING STREET CROSSING

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Introduction

Gait termination and initiation require a strict postural control in order to avoid a fall. Both paradigms have been studied extensively in laboratory conditions. It has been shown that during gait termination subjects modify ankle and knee kinematics while performing at least two steps prior to stopping [1]. Gait initiation requires the execution of anticipatory postural adjustments in order to reconfigure posture in order to establish favourable conditions for stepping [2]. The objective of this study is to quantify pedestrian kinematics while crossing the street in front of an incoming vehicle. Crossing the street requires stopping at the sidewalk and then initiating walking. We expect more variability in pedestrians' motor behaviour as compared to what is normally observed in a gait laboratory.

Methods

15 subjects (8 women, age: 37.6 ± 7.6 yrs, height: 1.7 ± 0.07 m, weight: 65 ± 6.2 kg) participated in the experiment after providing written consent. 17 inertial units (Xsens Technologies B.V., the Netherlands) were used to capture body kinematics. Volunteers walked in the direction of a road junction and waited for a traffic light to turn green then cross. An optical sensor allowed an incoming car to activate the traffic light when the car was at a distance of 10 meters from the zebra crossing. The task was repeated 6 times by each participant.

Results

Subjects started decelerating at an average distance of 2.02 ± 0.39 m from the road. The mean duration of the deceleration phase was 2.95 ± 0.65 s. While decelerating, subjects executed 3 to 5 steps in 88.8% of the trials. The steady-state velocity prior to deceleration was not correlated with the duration of the deceleration phase ($r^2 = 0.02$). However, the distance from the zebra-crossing measured at the instant of onset of deceleration was correlated with the braking phase ($r^2 = 0.7$). In 86.5 % of trials, subjects performed anticipatory postural adjustments prior to lifting the swing leg and cross the street. Anticipatory postural adjustments were observed as a hip abduction of the swing leg and a forward inclination of the whole body around the ankle. The onsets of hip abduction and forward inclination were at times dissociated. The duration of anticipatory postural adjustment was 0.81 ± 0.43 s. Surprisingly, the duration of anticipatory postural adjustments was not correlated with forward velocity measured at the instant of foot contact ($r^2 = 0.11$). During the crossing phase, the subjects reached steady-state velocity and step length at the third foot contact. Subjects' trunk inclination measured at foot contact was greater during the first two steps as compared to the third step.

Conclusions

This study is the first to our knowledge to quantify kinematics of healthy young pedestrians while crossing the street in front of an incoming vehicle. The results suggest that gait initiation and termination can be more challenging and 'less automatic' in a real-life situation. This is expected since crossing the street is a complicated sensorimotor integration and cognitive task that is coupled with the already complex motor programs of gait termination and initiation. Future experiments will combine eye tracking and body kinematics in order to examine both visual integration as well as motor execution of both young and elderly subjects.

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ARE POSTURAL RESPONSES AND ANTICIPATORY POSTURAL ADJUSTMENTS MEDIATED BY DIFFERENT NEURAL NETWORKS?

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Introduction
People with Parkinson's disease (PD) exhibit deficits in postural control, including small anticipatory postural adjustments (APAs) prior to a voluntary step [1] and small automatic postural responses (APRs) to a an external perturbation [2]. However, it is not clear whether the same PD-related neural network disorders contribute to both types of postural impairments. Previous findings showed a re-organization of functional communication between the right supplementary motor area (SMA) with the brainstem pedunculopontine nucleus (PPN) in people with PD who show freezing of gait. The objective of this study was to investigate whether APAs and/or APRs are associated with abnormalities in the same SMA-brainstem networks in PD with and without freezing of gait.

Methods
Twenty-four subjects (MDS-UPDRS-III: 45.3 $\pm$ 15) with freezing and 24 PD subjects without freezing (MDS-UPDRS-III: 37 $\pm$ 10.3) who had PD participated in the study. Behavioral outcome measures derived from 3 body-worn, inertial sensors were: 1) Amplitude of lateral APA prior to the first voluntary step for a 7 meter walk [1] and 2) Time to stabilize equilibrium after a backward Push & Release maneuver. Functional connectivity between SMA (anterior & posterior) and the following locomotor hubs were investigated: 1) subthalamic nucleus (STN) and 2) PPN, within each hemisphere. Associations between the behavioral measures and functional connectivity among the 8 brain regions of interest were investigated using linear partial correlations, controlled for disease duration.

Results
Freezers showed a significant positive association between amplitude of APA and right anterior SMA-PPN connectivity (r = 0.64, p = 0.003). In contrast, time to return to equilibrium with a backward stepping response was correlated with left posterior SMA-STN functional connectivity between (r = 0.58, p = 0.007). Only freezers showed a relationship between postural disorders and SMA-brainstem networks.

Conclusions
Our results suggest that the hyper-direct pathway between SMA-STN may be involved in control of APRs whereas the SMA-PPN pathway is involved with control

of APAs prior to voluntary step initiation. These network relationships with postural performance were only observed in people with PD who had freezing of gait and were more severely affected, suggesting lack of compensatory mechanisms.

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Lower limb loading during gait in patients with bilateral total hip replacement

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Introduction

The number of total hip replacements (THR) has been steadily increasing, mostly due to increase in life expectancy and decrease in physical activity. At the same time, the average age of patients undergoing THR decreases [1]. Aghayev et al. [2] recommend for people with bilateral osteoarthritis minimizing the time between THRs for each hip. After THR, the gait pattern changes [3]. The gait pattern remains different when compared to healthy persons even after a significant improvement 2–6 months after surgery [4]. The aim of the study is to assess the effect of the second stage of bilateral THR on lower limb loading during the stance phase of gait.

Methods

Nine patients after two-stage bilateral THR (4 men, 5 women, age 65 ± 8.4 years, body height 170.8 ± 7.7 cm, weight 78.3 ± 13.1 kg, 12.2 ± 3.5 months since the second stage THR) and nine controls (4 men, 5 women, age 65 ± 6.7 years, body height 170.7 ± 8.2 cm, weight 81.0 ± 15.8 kg) participated in the study. All participants underwent 8–10 walking trials at their natural speed, 5 trials were selected for further analysis. Kinetic data were collected with two force plates. The Wilcoxon sign-rank test was used to assess differences between the leg operated in the first stage (L1) and the leg operated in the second stage (L2). The Mann-Whitney U-test was used to compare the patients and controls. The level of statistical significance was set at 0.05.

Results

Compared to the controls, the minimum of the vertical force in the midstance and final stance was significantly ($p = 0.021$) higher for the L2. Similarly, the impulse of the vertical force in the braking phase was significantly ($p = 0.027$) higher for the L2. The time to reach the maximum of the vertical force in the braking phase was significantly higher both for the L2 ($p = 0.008$) and L1 ($p = 0.027$). No statistically significant differences were found between L1 and L2.

Conclusions

The results suggest that lower limb loading during gait in the persons after bilateral THR is symmetrical. Compared with the controls, the patients after a year since the second stage THR loaded their L2 more and the load was transferred to it more slowly.

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TEMPORALLY COORDINATED MECHANISMS OF BALANCE CONTROL DURING WALKING

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Neural control of balance has been studied extensively in standing, using a variety of techniques with quiet unperturbed stance as well as sensory and mechanical perturbations. Despite the vast knowledge gained regarding balance control during standing, such findings do not necessarily translate to balance control during walking. The main reason is the gait cycle. While responses to disturbances during standing follow a short-medium-long latency response pattern over 50-200 ms involving a proximal-to-distal pattern (or vice versa) of muscular activation, responses to disturbances during walking can occur anytime over the much longer (600 ms) gait cycle of steady state walking. Critically, body configuration changes dramatically over the gait cycle (e.g., double vs. single stance), necessitating different mechanisms to maintain upright balance at different points of the cycle.

One common principle to maintain upright balance during standing and walking is that the base of support must (on average) be kept under the body's center of mass (CoM). The locomotion literature has focused extensively on one particular mechanism to achieve this: foot placement control. When the central nervous system (CNS) senses a movement of the CoM to the right, e.g., it changes the foot placement of the next step to the right. However, recent studies have suggested that to achieve flexible control of upright stance during walking, foot placement control is only one in a series of several temporally coordinated control actions. Consider the demands on upright stability while crossing a busy intersection with many other pedestrians. Continuous small changes in direction are required to avoid pedestrians walking towards you while progressing under the time constraints of the crosswalk signal. These small changes, essentially responses to disturbances during steady-state walking, can occur at any time during the gait cycle. To adapt flexibly, using only one balance mechanism (i.e., foot placement change) available only during a short time window of the gait cycle, is not sufficient. Instead, multiple balance mechanisms which are temporally coordinated lead to the most flexible response to disturbances while walking. I will discuss how task, environmental constraints and neurological deficits may change the availability of these mechanisms and how loss of any one of these mechanisms requires compensation from a remaining mechanism that is not optimal for flexible, stable locomotion.

SAMPLE ENTROPY ANALYSIS OF POSTURAL SWAY IN PARKINSON'S DISEASE – PILOT STUDY

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Introduction

Parkinson's disease (PD) is a neurodegenerative disease, which is characterized by tremor, muscle rigidity and bradykinesia, what may affect the posture and the body balance. The dynamical structure of postural sway during quiet standing especialy its regularity was recently found to be related to the amount of attention invested in postural control [1]. The regularity of the COP signal was quantified on the basis of sample entropy [2] and the automatic postural control processes increase the sample entropy, while volitional control decreases it [3]. Some authors observed more regular COP signal in clinical groups compared to healthy controls [4]. Therefore, the aim of the study was to assess the COP signal regularity using sample entropy in patients with Parkinson's disease.

Methods

The research was conducted on17 patients with PD at stage III (age: 66 ± 6.6 years; body mass: 76 ± 12.6 kg; height: 168 ± 5.4 cm) and 17 older healthy adults (age: 70.2 ± 4.8 lat; body mass: 72.8 ± 7.7 kg; height: 164.1 ± 8.0 cm). The procedure consited of quiet standing with open eyes (OE) and closed eyes (CE). Each trial lasted 30s and was repeated three times. We analyzed the velocity COP [cm/s], rangeCOP [cm], root mean square COP [cm] and sample entropy.

Results

The values of sample entropy in open eyes was significantly lower ($p = 0.021$) in the PD group compared to the control group. Also in closed eyes the sample entropy was lower in the PD group, whereas these differences was not significant ($p = 0.360$). In both open and closed eyes the data showed significantly higher values of the measured parameters of raCOP (OO: $p = 0.009$, OZ: $p = 0.0404$), rmsCOP (OO: $p = 0.003$; OZ: $p = 0.028$) and insignificantly higher vCOP (OO: $p = 0.070$; OZ: $p = 0.691$) in the PD compared to the control group.

Conclusions

Lower values of sample entropy in the PD group suggest the more regular COP signal, which indicates the less automatic postural control. The PD patients have to invested more attention in postural control than healthy subjects.

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FUNCTIONAL REACH AND DYNAMIC BALANCE OF HEALTHY 11-YEAR-OLD CHILDREN

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Introduction

Standing balance control strongly depends on the adequate integration of sensory information and the support area [1]. Functional reach (FR) test [2] is applied for dynamic balance assessment of different age groups. Three strategies of FR exist: ankle, hip and mixed [3], defined by the changes in the ankle and hip joints during the reaching task. The influence of sensory conflict and the support area on these strategies has not been studied. Our aim was to compare the reaching strategies adopted by healthy 11-year-old children and adult controls and to assess the ability of the children to adapt to different task conditions.

Methods

Eighteen children – boys and girls (mean age 11 ± 0.2 years) and 18 adults (mean age 32.6 ± 4.9 years) performed FR in random order in 4 sensory conditions: eyes-open, eyes-closed, head-extended with eyes open or closed on normal (feet in 30 degrees, 3 cm between heels) and narrow support (feet side to side). Each trial lasted 30 s. Center of pressure (COP) sway was recorded by a pedobarographic platform Tekscan, 30 fps. Kinematic data was collected by video recording, 60 fps, 1280x720 px (GoPro Hero 5 Black). We applied specialized software for automatic object tracking (Kinovea) and two-dimensional kinetic and kinematic analysis [4]. Measures explored: COP displacements, FR length (normalized by subjects' height) and angles in the hip and ankle joints during reach, defining the adopted strategies.

Results

Almost all investigated subjects (children and adults) adopted the hip FR strategy. The ankle strategy was a little bit more expressed by children and 1 child adopted mixed FR strategy. All subjects were consistent in their choice of reaching strategy. This is in line with previous studies based on different experimental paradigms [5, 6] that also found adult-like postural behavior in children. The narrow support and sensory conflict deteriorated dynamic standing balance and FR diminished in both age groups. However, children's normalized FR was shorter than the controls across all experimental conditions. Narrowing the support increased the lateral COP sway in both groups. Children's lateral sway increased on both supports in absence of visual information, in adults this was expressed only in the narrow support series.

Conclusions

Children's dynamic standing balance is more visual dependent compared with adults, especially in the normal support series. Despite the sensory conflict and narrow support, which deteriorate the FR performance and dynamic standing balance, the 11-year-old chlidren showed adult-like general postural behavior.

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EFFECT OF SENSORIMOTOR FOOT ORTHOSES ON LOWER LIMB GAIT KINEMATICS

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Introduction

Sensorimotor foot orthoses (FO) is one of the recent concepts of FO. This concept is reported to deliver both mechanical effect and influence muscle function [1]. Yet, up to date, there is little scientific evidence to this concept. The aim of the study is to determine effects of sensorimotor FO on lower limb gait kinematics.

Methods

Ten asymptomatic subjects (6 males, 4 females, mean age 22.7 ± 3.3, height 174.2 ± 8.8, body mass 66.5 ± 6.1) were tested under three conditions: a) no FO, b) FO with retrocapital pad attached behind second to fifth metatarsal with elevation to medial side (RM), c) FO with an elevation to lateral side (RL). The same type of shoes (ProTouch Drop Shot) was used for all measurements. Eight trials were recorded for each condition using a Vicon MX system (200 Hz). There was 5 minute initial familiarization and “wash out” period between conditions. A Repeated Measures ANOVA with post hoc pairwise comparison using the Bonferroni correction method was used to explore the differences between conditions, with the significance level 0.05. The dependent variables were peak FP angle during midstance, peak knee internal rotation during midstance, and peak hip internal rotation during midstance.

Results

There was a significant difference at the peak foot progression angle during midstance ($p = 0.004$; $\eta_p^2 = 0.453$). Further pairwise comparisons revealed that both RM and RL significantly increased external rotation of the foot, RM by 1.14 degrees ($p = 0.025$), RL by 1.28 degrees ($p = 0.013$). There was significant difference in peak knee internal rotation but only at dominant lower limb ($p = 0.017$, $\eta_p^2 = 0.365$). Further pairwise comparisons revealed that both RM and RL increased the peak internal rotation, RL significantly by 1.87 degrees ($p = 0.023$). Although both RM and RL conditions indicated increase of the peak hip internal rotation, there was no significant difference between them and no FO condition.

Conclusions

The results of this study show that sensorimotor FO significantly affected the foot rotation, only partially knee kinematics, and there was no significant difference in the hip kinematics. This implies that the effect of immediate foot orthoses application is strongest in location of application (the foot) and weakens with growing distance from the location of application, which corresponds with current knowledge [2]. Our findings show that both FO affected foot rotation in the same way, albeit by different amounts. This is not in agreement with their perceive function, with RL theoretically promoting external rotation, and RM theoretically promoting internal rotation.

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EFFECT OF GAIT IMAGINATION ON LOWER LIMB MUSCLE ACTIVITY

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Introduction

Motor imagery represents a pure cognitive process, which can positively influence motor performance in both healthy subjects and in a wide range of patients with movement disorders. Specifically walking ability has been shown to improve after motor imagery exercises. The facilitatory effect of motor imagery on muscle activity has been demonstrated compared to rest conditions for upper limb movements[1-3], however further work is required to consider the effect during lower limb movements. The question is how the imagination of gait influences lower limb muscle activity.

Methods

27 healthy subjects (age 24.4 ± 1.3 yrs) participated in this study. Only participants with at least moderate visual and kinesthetic imagery ability, evaluated by Revised Movement Imagery Questionnaire (MIQ-R), were included in the study. Participanats were asked to stand and perform (I) standing with no imagination, (II) standing with imagination of gait, (III) real walking, (IV) imagination of gait after walking. During these experimental conditions surface electromyographic (sEMG) activity was measured from the dominant lower limb muscles including; biceps femoris, rectus femoris, gastrocnemius medialis, and tibialis anterior. The mean RMS EMG values for all tasks were compared using non-parametric tests for statistical analysis. The alpha value was set at $p < 0.05$.

Results

EMG activity from rectus femoris ($p = 0.03$) and biceps femoris ($p = 0.01$) increased for gait imagery task (II) in comparison to the rest condition (I). On the contrary muscle activity from tibialis anterior ($p = 0.01$) decreased for gait imagery after real walking (III). For all other comparisons and muscles the imagination of gait after real walking showed no significant differences.

Conclusions

The increase of EMG rectus femoris and biceps femoris activity during motor imagery reflects a number of facilitatory factors, including default posture, character of imagined object or complexity of imaginary movement [1,4]. Our study demonstrates a facilitatory effect of gait imagination on lower limb muscle activity for proximal lower limb muscles. These findings help the understanding of the effect of gait imagery on motor control system and demonstrates the potential clinical utility of this technique.

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GAIT DISORDERS IN PATIENTS WITH GENERALISED DYSTONIA AFTER GPI-DBS: INSIGHT FROM EYE MOVEMENT STUDY

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Introduction
Deep brain stimulation of internal pallidum (GPi-DBS) is an established treatment option in medically refractory isolated generalised dystonia with sustained effect in the long-term [1]. In certain cases gait disorders, most frequently freezing of gait, may occur post-operatively. Previous research has shown the utility of eye movement studies in elucidation of underlying mechanisms of gait disorders, possibly due to shared neuroanatomical networks [2]. The aim of our study was to assess ocular movements in patients with isolated generalised dystonia long-term GPi-DBS and gait disorders.

Methods
We screened for self-reported post-operative gait disorders in the population of long-term GPi-DBS from our centre (5 years and more since DBS surgery, n = 22). In these patients prosaccades and antisaccade were examined in two stages. Firstly, the patients´stimulation parameters were switched into the stage of “bad gait” and the ocular movements were recorded. Secondly, the same procedure was repeated with “good gait” stimulation parameters. The performance in the eye movement tasks was compared to age-matched healthy population.

Results
In our cohort we identified three patients with post-operative gait disorders; two patients had gait freezing and one patient reported unusual feeling of unsteadiness in turns. When assessing the eye movement performance, in the “bad gate” stage two patients had pathological performance in the antisaccade task. One patient had faster responses with higher percentage of errors and the second one had unilaterally prolonged response with higher percentage of errors. Third patient had prolonged prosaccades latencies unilaterally in both gait stages which was interestingly more impaired in the stage “good gait”. Impaired antisaccade performance may point to the stimulation-induced disruption of fronto-striatal circuits and the stimulation of anterior limb of internal capsule may be responsible for increased latencies in prosaccades.

Conclusions
Gait disorders in long-term GPi-DBS patients with isolated generalised dystonia seem to be a result of clinical features of dystonia and the spread of current to surrounding structures.

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COMPARISON OF LOWER LIMB KINEMATICS DURING GAIT BETWEEN PATIENTS AFTER PRIMARY AND REVISION TOTAL HIP REPLACEMENT

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Introduction

After the first total hip replacement (THR) occurs primarily to relief from pain, as well as gradually improving the range of motion, especially in the sagittal plane of the hip joint [1]. However, compared to the group of healthy individuals, the walking stereotype is different [2]. The second, ie revision, surgery often occurs also due to wrong gait performance, overloading the bearing joints, both on the operated and non-operated lower limbs. The aim of this study was to compare lower limb and pelvis kinematics between patients after primary and revision THR.

Methods

Nineteen patients (11 women, 8 men), aged 61.9 ± 13.9 years, height 168.2 ± 8.0 cm, weight 77.4 ± 10.6 kg who underwent a primary unilateral THR (1 year after surgery) and eighteen patients (9 women, 9 men), aged 59.5 ± 8.0 years, height 167.4 ± 8.9 cm, weight 77.2 ± 18.1 kg who underwent a revision unilateral THR (7.4 ± 4.4 years after surgery) were included. Gait assessments were conducted using a 7 camera Vicon optoelectronic system (Oxford Metrics Group, UK) and 2 Kistler 9286AA force plates (Kistler Instrumente AG, Winterthur, Switzerland). Subjects were asked to walk barefoot on a 10m long walkway. The test statistics within kinematic variables were examined with two-sample t-test, Mann-Whitney test or Welch's t-test.

Results

In comparison of operated lower limbs, a greater ranges of motion were found in the group after primary THR, in the ankle dorsal flexion ($p = 0.037$), knee flexion - stance ($p = 0.024$), knee extension - stance ($p = 0.035$) and hip flexion ($p = 0.040$). The only statistically significant difference between non-operated limbs was found in the total range of motion of hip joint. It was significantly higher in patients after revision THR ($p = 0.003$).

Conclusions

Due to the similar age of both groups, we can exclude the age factor as an explanation of decreased range of motion in patients after revision THR, which is in contradiction with Mazzoli et al. [1]. It is not surprising that the second surgery significantly reduces mobility of the lower limb joints (ankle, knee and hip), and on the other hand overloads contralateral (non-operated) hip joint with its excessive range of motion. But it is necessary to point out to need for long-term rehabilitation, mainly kinesiotherapy with accent on gait cycle performance as prevention of later difficulties (especially functional).

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PROCESSING OF ILLUSIONAL VISUAL INFORMATION DURING UPRIGHT STANCE IN SENIOR AND DEMENTED PATIENTS

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Introduction

Upright stance control deteriorates with increased age [1]. Impairment of upright stance is more frequent in demented seniors when compared to healthy seniors [2]. Our experiment observes effects of faulty visual information which elicits illusion of body movement (vection) and perturbs upright stance. We assume that demented seniors have lower ability to adapt illusional movement and therefore are more prone to erroneous evaluation of sensory conflict.

Methods

Group of healthy seniors consists of 3 females and 7 males (mean age 72.2 years (SD = 4.2). Group of demented patients consists of 5 males and 5 females (mean age 74.2 years (SD = 7.2) – their cognitive deficit reached the stage of clinically definitive dementia of vascular or Alzheimer disease origin and was confirmed with neuropsychological testing. Centre of pressure (CoP) displacements were recorded using force platform. Participants stood quietly on the platform at a distance of 50 cm from the wide-screen visual scene display. The quite stance (50 seconds) was perturbed by constant linear or rotational visual scene motion (20 seconds). Illusional scene motion was presented using rear projection covering the whole visual field (screen positioned 0.5 meter from study person). We performed 5 measurements in each direction of illusional movement (left, right, forward, backward), using force platform. Body sway in both directions was recorded and analysed using MATLAB [4]. Statistical analysis was performed both within and between groups, using analysis of variance (ANOVA, $p = 0.05$) of body sway compared between groups are in Figure 1.

Results

Constant visual scene motion induced forward body leaning (“on” effect). The opposite effect was observed at the stop of visual scene motion (“off” effect). Rotational visual scene induced less pronounced effects in medio-lateral direction. The visual scene motion induced larger CoP displacements in patients; however these were not statistically significant. Significant differences were detected for velocity index of body sway, which was increased in demented seniors when compared to undemented counterparts - during stimulation significantly different in left and forward direction, but even more pronounced after stimulation (“post effect”) in all but backward direction (see Figure 1). Backward direction of stimulation did not elicit significantly different response (we can speculate if this was due to limited range - further backward sway may lead to fall). Further, the postural responses to visual scene perturbation were less variable in demented patients than in cognitively intact group. Overall, our findings sustain theory, that elderly patients with cognitive impairment are more sensitive to visual scene perturbations.

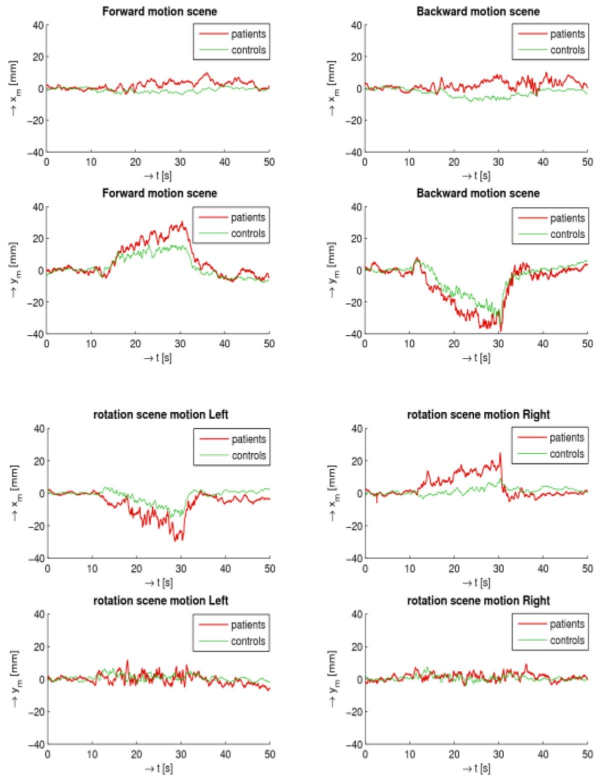

***Figure 1.** Comparison of body sway between demented (dark grey) and healthy seniors (light grey).*

Conclusions

Actions of re-weighting sensory inputs during upright stance are probably altered in patients with cognitive impairment. Perceiving of visual information can be ambiguous in varying environment. Therefore it requires correct processing of sensory information. Altered sensory processing in demented patients can lead to the instability in certain situations.

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GAIT AND BALANCE DISORDERS IN PATIENTS WITH PD – DETECTION OF SPECIFIC PROBLEMATIC SITUATIONS

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Introduction
Gait and balance disorders are one of the most disabling symptoms in patients with Parkinson's disease (PD). These symptoms are more frequent with the disease progression. The most serious consequences are recurrent falls or feeling of instability during the gait, which have significant impact on the quality of life in PD patients. There are some specific (collision) situations in patient's life that can cause feeling of instability, increase the risk of fall or aggravate movements overall. We can model the specific problematic situations as virtual paradigms in the virtual reality. These can help us to diagnose and treat problems with gait and balance.

Methods
We did a cross-sectional study based on the data that we have collected by processing the non–validated questionnaire which consisted of 20 questions, each focused on specific collision situation with dichotomous type of response (YES/NO), with the possibility to indicate intensity on the visual analogue scale from 0 to 10.

Results
We administered our non-validated questionnaire to 68 patients with PD (37 men) with the mean age 63.6 ± 10.4, duration of disease 7.6 ± 4.7, H&Y stage 2.39 ± 0.64. By using analytical processing, we found out that 91% of patients reported problems with gait and balance. One of the most important triggers that caused problems with gait or balance was execution of tasks under time pressure (reported by 70% of patients). 68% of patients complained of movement difficulties in poor light conditions with an average intensity of 2.93 ± 3.08. 67.2% of patients reported feeling of feet glued to the floor when they are trying to initiate the step, during turning and walking with an average intensity of 3.28 ± 3.16. 62.1% of patients reported problems with an average intensity of 3.14 ± 3.44 when walking in crowded areas. We also tried to correlate some specific (collision) situations with the disease duration. We used Spearman's correlation to find out that longer disease duration correlates with collision situations mostly when patients are trying to go through narrow space ($r = 0.30$), when situation suddenly changed ($r = 0.36$), when there is some obstacle ($r = 0.32$) or during the dualtasking ($r = 0.30$).

Conclusions
With this cross-sectional study, we have mapped individual collision situations causing balance and gait disorders and their severity in patients with PD. By identifying situations that significantly aggravate balance and gait we have the opportunity to early diagnose and treat postural instability and related complications

and focus on specific problems in PD patients with longer duration of the disease by using virtual reality.

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IMMEDIATE EFFECT OF RETROCAPITAL BARS OF SENSORIMOTOR INSOLES ON RELATIVE TORSION BETWEEN THE PELVIS AND THE FOOT DURING THE STANCE PHASE OF GAIT CYCLE IN ASYMPTOMATIC HEALTHY ADULTS

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Introduction

Free moment (FM) attracted attention in recent literature and could be used as a meaningful index of the torsional stress applied on lower limbs during gait cycle [1]. Therefore, influencing the torsional stress could be possibly beneficial in patients with torsional stress related injuries.

Relative torsion (RT) expressed as the angle of rotation between the pelvis and the foot progression angle (FPA) during walking can explain the magnitude of the FM [1]. Because retrocapital bars of so-called sensorimotor insoles (SMI) are thought to modify the FPA [2], the influence of these elements on lower limbs torsion during the stance phase of gait cycle (SPGC) was investigated.

Methods

Repeated measures design was used. Eleven asymptomatic adults (mean age 23.0 ± 3.3 years, height 174.4 ± 8.4 cm, body mass 66.9 ± 6.0 kg) participated in this study.Participants were fitted with a correctly sized pair of uniform sport shoes ProTouch Drop Shot and a base sole (BS) without any orthotic element. Afterward, they performed several trials at a self-selected speed both for familiarization and testing. Condition with a BS alone was followed by trials with a retrocapital medial (RM) or lateral (RL) bar attached to the BS in random order. Data were collected during one session using the Vicon MX system (6 cameras, sampling rate 200 Hz). Retro-reflective markers were not removed during the session. Angles of the pelvis and lower limb joints were calculated using the Plug-in Gait model (16 markers). RT was established as a difference between the FPA and pelvic rotation.Statistical analysis was performed using SPSS (version 24.0) with a ANOVA repeated measures ($p < 0.05$ with post-hoc Bonferroni correction).

Results

Significant differences were found for the minimum ($p = .016$) and maximum ($p = .036$) of the RT during the SPGC. No significant difference was found for the range of RT ($p = .621$).Post-hoc test showed significant differences between the RM and BS for the minimum ($p = .028$) and between the RL and BS both for the minimum ($p = .025$) and maximum ($p = .030$) of the RT during the SPGC.

Conclusions

Our findings show significant differences in RT between the RM, RL and BS. Post-hoc test, however, did not show any differences between the two retrocapital bars themselves.This could suggest, that the direction of inclination does not have any influence on the RT or that the level of inclination was not sufficient enough to distinguish between those two conditions.

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SYNERGIC CONTROL OF POSTURE: IMPAIRED STABILITY AND AGILITY IN PARKINSON'S DISEASE

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Introduction

Vertical posture in Parkinson's disease (PD) is characterized by low stability (as reflected in likely loss of balance under postural perturbations) and difficulty in movement initiation (as reflected in episodes of freezing). These two symptoms seem poorly compatible because, theoretically, low stability should make movement initiation easier. We explored the effect of PD on these two aspects of posture using the concept of posture-stabilizing synergies and the computational framework of the uncontrolled manifold (UCM) hypothesis [1]. Most studies involved PD patients at stage-II (Hoehn-Yahr), which is defined as a stage with no clinically identifiable problems with postural stability.

Methods

The subjects performed several tasks including cyclical voluntary body sway between visually presented targets and self-paced release of a load from extended arms. Surface EMG signals were used to identify muscle groups (M-modes) with parallel scaling of activation levels [2]. We used principal component analysis with rotation and factor extraction to obtain a set of orthogonal M-modes, which is important for the next steps of analysis. Mapping from M-mode changes to shifts of the center of pressure (COP) was defined using multiple linear regression. Two methods were used to quantify M-mode synergies stabilizing COP trajectory in the anterior-posterior direction. The first was analysis of inter-trial (or inter-cycle) variance in the M-mode space resulting in two variance components, those with no effects on COP coordinates (within the UCM, V_{UCM}) and those shifting COP (orthogonal to the UCM, V_{ORT}). The second was analysis of motor equivalence resulting in measures of displacement within the M-mode space between comparable phases of the voluntary postural sway, along the UCM (motor equivalent, ME) and orthogonal to the UCM (non-motor equivalent, nME). The timing and magnitude of feed-forward adjustments in synergies in preparation to a self-triggered perturbation (anticipatory synergy adjustments, ASAs, [3]) were computed as indices of agility.

Results

PD patients in an on-drug state showed significantly reduced indices of ASA, significantly lower relative amounts of V_{UCM}, and significantly smaller ME as compared to age-matched controls [4]. Dopamine-replacement medications led to an improvement in the indices of both stability and agility. Deep brain stimulation (DBS of the subthalamic nucleus or globus pallidus internus) improved indices of agility but not of stability [5]. These observations provide possible mechanisms for the reported increase in fall rates in PD patients on DBS. The indices of synergic control computed for the postural tasks and for the four-finger accurate force production tasks on and off DBS showed significant correlations between the indices for the two tasks.

Conclusions

These results suggest the existence of brain mechanisms for synergic control shared across tasks and effector sets. We conclude that quantitative analysis of the synergic control of posture is highly sensitive to PD and to effects of treatment. The contrasting effects of DBS suggest that the circuitry involved in the control of postural stability is at least partly different from the one responsible for agility.

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POSTURAL INSTABILITY IN AUTONOMOUS VEHICLES FOLLOWING FRONT-SEAT PASSENGER EXPOSURE

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Introduction

The future of vehicle transportation is rapidly moving towards autonomous vehicles. One unaddressed, possible safety concern is postural instability among passengers following a drive, which may induce motion sickness and thereby potentially increase the risk of falling during post-exposure activities [1,2]. Prior research has shown that exposure to virtual vehicle simulations and motion platforms contributes to a temporary increase in postural instability due in part to motion sickness symptoms [2-4]. Although simulations provide visual and auditory stimuli that are representative of real drives, the forces that act on passengers differ in a physical setting and influence passengers' postures [3]. The goal of this study was to characterize the effects of riding in the front-seat of a sedan on balance.

Methods

Forty-six adults (20 males, 26 females; aged 18 to 78 years (41.02 ± 20.68 years)) were exposed to scripted drives with varying speeds and tasks [5]. Participants were randomly assigned to either a moderate or low acceleration driving group. Within each group, participants completed two 20-minute drives as front-seat passengers, one of which involved the simultaneous completion of a task consisting of a tablet-based questionnaire that evaluated basic reading comprehension, visual search, pattern logic, and spatial awareness skills.

Participants completed three 30-second repetitions of two balance exercises before and after each drive. The first exercise required participants to stand with feet in the tandem Romberg position on a firm surface with their eyes open (EO). The second exercise required participants to stand in the Romberg position on a foam surface with their eyes closed (EC). A smartphone-based inertial measurement unit [6] was used to capture the trunk kinematics. Six parameters were derived from these data: root-mean-square (RMS) of angular position and velocity (A/P and M/L direction), and the 95% elliptical area (EA) and path length of the position trajectory. Paired non-parametric tests (Wilcoxon signed-rank and rank sum) were performed to detect significant postural changes with respect to driving conditions using a significance level of 0.05.

Results

In both exercises, post-drive RMS velocity in the A/P direction was significantly greater than pre-drive values across all drive conditions. However, path length and velocity in the M/L direction were significantly greater in every condition for only the EC exercise. Among drive conditions, the post-drive measurements of M/L RMS ($p<0.01$) and EA ($p<0.05$) in the moderate-task drive were significantly higher than their respective moderate-no task measurements in the EC exercise. In the EO exercise, A/P RMS ($p < 0.01$) and path length ($p < 0.05$) measurements were significantly higher in the low-task condition than the low-no task condition.

Conclusions

Front-seat passengers demonstrated increased instability across multiple measures in standing exercises after a scripted drive through an urban environment. Moderate and low acceleration driving conditions, both with and without the task, induced changes in balance. Future work should explore the relationship between vehicular induced motion sickness symptoms and postural instability.

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CHANGE IN BODY AND MIND STATES WITH STRETCHING EXERCISE IMPROVING THE POSTURE IN SCHOOL REFUSAL

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Introduction

Good posture is important for health, while poor posture will give us bad influences on the body about shoulder stiffness, backache, and so on. Posture is closely related to the psychological aspects. Therefore, it is expected that setting the good posture leads to the improvement of health problems as mentioned above. The present study aimed to examine postural alignment and the shape of spinal curvature in students who have refused to attend school, evaluate a change in the mind and body states following improved posture nearer to ideal alignment. It seems many of the children have some kind of problem. We think that this study is something good that we can expect to obtain new knowledge to support them.

Methods

Sixty-five high school students experienced the school refusal participated in this experiment. They carried out simple and effective body stretches improving posture for two months. Their posture and state of mind were measured in the following method: postural alignment and spinal curve in a sagittal plane, foot pressure distribution, and questionnaire survey (general health and subjective adjustment). These measurements were performed in three periods: 1.before stretching (present posture data); 2.just after stretching (improved posture data); 3.two months later (continue to improve the posture).

Results

They could adjust the good alignment of posture by the stretching to improve posture, and they have kept the good alignment for about two months. Moreover, the flexibility of their body was significantly enhanced. In the questionnaire survey, it is found that the participants who could be more improved in their posture, caused a change in the mental stability, significantly decreased a sense of inferiority.

Conclusions

The finding of this study suggested that the stretch was suitable for improving the posture of the student experienced school refusal, revealed that setting the good posture result in improving the mental health and physical condition. It is expected that this study will lead to enhancing the ability to adjust to school or new environment, and preventing school refusal.

CORTICAL ACTIVITY TO MEASURE AUTOMATICITY OF TURNING WITH AND WITHOUT VIBROTACTILE CUES

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Introduction

Difficulty with turning often presents in Parkinson's disease (PD) and can result in freezing episodes or falls. Cueing strategies have been used to improve gait in PD, but it is unclear if cues increase or decrease the use of executive-attentional processes associated with activation of the pre-frontal cortex (PFC) and loss of automaticity. This study aimed to evaluate frontal lobe activity during turning behavior in people with PD and healthy controls and to evaluate the effect of closed-loop, vibrotactile biofeedback versus open-loop, continuous cueing on automaticity (PFC activity) during turning in people with PD.

Methods

PFC activity during walking and turning was recorded in 9 healthy elderly subjects and 28 PD participants while OFF medication (MDS-UPDRS: 42.5±13.8, age: 67.3±5.6years) using mobile, functional near infra-red spectroscopy (fNIRS). Inertial sensors measured quality of turns. Participants walked and turned (180°, 360°) and only the subjects with PD repeated the task with and without biofeedback or metronome-like vibrotactile cueing. Closed-loop biofeedback involved vibrotactile cues presented on the right and left wrists during right and left stance, respectively, whereas open-loop cueing involved the same intensity (similar to a cell phone) of vibrotactile stimulation presented for 250ms every 750ms. The primary outcome was cortical activation, specifically change in oxygenated hemoglobin (HbO_2) 6 sec. prior-to and during turning.

Results

PFC activation is significantly higher during turning compared to walking in the PD group, while healthy controls show an opposite trend. In addition, a greater PFC activation is required for sharper turns (180º vs 360º, $p = .021$). Overall, vibrotactile cues significantly impacted cortical activity during turning in PD (Friedman's; $X^2 = 7.95$, $p = 0.047$). Cortical activity was reduced with biofeedback during a 360° turn (-0.25 µmol/l change in HbO2), which was not found during a 180° turn (+0.06 µmol/l change in HbO2). Interestingly, biofeedback increased cortical activity in the 6sec prior to a turn in PD within both conditions. There were no significant changes in turn metrics.

Conclusions

The higher PFC activity found prior to a turn and not during the turn, in healthy controls, might be due to the turn preparation, trend that was opposite in subjects with PD. Such findings may indicate that turning could be less automatic (that is it involves more PFC activity) in subjects with PD compared to healthy controls. Vibrotactile biofeedback or metronome-like cueing reduces PFC activation in people with PD, which may improve their automatic control of turning.

REACTION TIME, BODY BALANCE AND GAIT CHARACTERISTICS IN PARKINSON'S DISEASE PATIENTS ACROSS THE PROGRAM OF "DRY" IMMERSION

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Introduction

The condition of immersion without direct contact with water, known as "dry" immersion (DI), proved efficient to mitigate certain motor and non-motor symptoms in Parkinson's disease (PD) patients [1]. Namely, score of UPDRS-III, rigidity subtotal and Hamilton's depression rate scale (HDRS) have decreased by 15-20% after a program of DI sessions [1]. In this study we aimed at further evaluation of motor and non-motor deficits in PD patients with help of instrumented tests for neurocognitive speed, body balance and gait.

Methods

A total of 18 PD patients (11 m, 7 f, H&Y stage 1-3) participated in the program of DI. They stood immersed in a bathtub (MEDSIM, IBMP, Moscow, Russia, Twater = 31-32°C), wrapped in a thin waterproof material, head-out-of-water, 7 times (45 min each session) within 35 days. The data was collected in 4 study points: before the 1st (preDI), after the 7th immersion (DI7), and 2 weeks (2W) and 2 months post-DI (2M). The reference group (no-DI, n = 6) formed of PD patients was examined in the same study points, without application of DI. The neurocognitivistic speed was evaluated by simple reaction time (SRT) on light stimulus, choice reaction time (CRT) that is a reaction only on certain color, and SRT under condition of attention distraction (DA-SRT). In all tests reaction time (ms) and number of mistakes was evaluated. Also, the hand tapping score was measured by means of electronic pen (NS-Psychotest, Neirosoft Ltd., Ivanovo, Russia). The body balance was evaluated by stabilometry (ST150, MERA, Moscow, Russia) with eyes open and closed (30 s each), using length (L, mm), velocity (V, mm/s) and square (S, mm^2) of the center of gravity sway. Gait and postural reactions were assessed in the Timed Up and Go (TUG) test in single and dual-task forms, by means on motion video-capture (Biosoft, Moscow, Russia). The SPSS 21.0 (IBM Corp., USA) was used for statistics (Wilcoxon and Friedman non-parametric tests).

Results

Mean SRT centered around 290-300 ms preDI, and it was not modified across the whole study. Mean CRT was 542 ± 169 preDI, 487 ± 129 at DI7, 410 ± 51 (p = 0.017 to preDI) at 2W, and 421 ± 31 ms at 2M. Mean DA-SRT was 331 ± 41 preDI and 308 ± 24 ms at 2W (p = 0.028). The number of hand taps (around 200 in 30 s) did not change. The stabilometry parameters in "eyes-open" condition (post-DI to 2W): L - from 254 to 275 mm, V - 8.9 to 9.4 mm/s, and S - 231 to 214 mm^2, the velocity of walking (around 0.5 m/s) and rising up during sit-to-stand move (around 0.8 m/s) stood unchanged. The time of TUG at single (11.5 s) and dual task (15.2

s) did not change across the study. In the no-DI group, all metrics did not change across the study.

Conclusions

The program of DI sessions exerted the most prominent recovery effect on the tests with strong cognitive content (CRT, DA-SRT), while the body balance and gait mainly did not respond to DI. This is in line with earlier clinimetric data on stronger effect of DI program on mood (HDRS) and autonomic functions [2] compare to motor (UPDRS-III) scores [1]. Positive effects of DI became most significant 2 weeks after the program, but they vanished 2 month later. The cause of such time course needs further examination.

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HUMAN RESPONSES TO SUPPORT SURFACE TRANSLATION - BODY-FOOT PROPRIOCEPTION CAN REPLACE BODY-SPACE VESTIBULAR INPUT

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Introduction

Stance perturbations evoked by support surface (SS) translational acceleration differ in several respects from those evoked by SS tilt. Both evoke body deflections around the ankle joints, however, while body-space and body-foot angles differ with SS tilt, they are mechanically coupled with SS translation. Correspondingly, the vestibular body-space and ankle proprioceptive body-support signals differ with tilt, but are equal with translation. Therefore, we asked how the translation responses of subjects with well-compensated absence of vestibular function (AV subjects) compare to those of subjects with normal vestibular function (NV subjects). While previous work used predictable sine wave stimuli [1], we here used a pseudorandom stimulus pattern for SS translation stimuli to compare frequency response functions (FRF) between AV and NV subjects for eyes open (EO) and eyes closed (EC) conditions. Then, we sought to reproduce the FRFs of both subject groups using a simulation model [2].

Methods

NV subjects (n = 7) and AV subjects (n = 7) were standing upright on a motion platform that was translated in the body's sagittal plane using a PRTS stimulus (see [3]; stimulus frequency range: 0.01-2 Hz) with peak-to-peak amplitudes of 3.5 cm and of 7.0 cm in the two visual conditions eyes open, EO, and eyes closed, EC. Body sway responses were measured in °/s using an optoelectronic device and were expressed as gain, phase, and coherence curves across stimulus frequency for body COM, trunk, and the leg segment.

Results

Gain, phase and coherence curves were in general similar in the two subject groups, this with EC and EO. Considerable differences concerned the trunk segment sway in the frequency range of 0.3-2 Hz in the EC condition. Here, AV subjects showed larger trunk sway (differences of mean gain compared to VL subjects: 0.4-0.7 and 0.4-1.2 for 3.5 cm and 7 cm stimuli, respectively). The model simulations were able to capture the main features of the gain, phase and coherence FRF curves for both the EC and the EO conditions similarly with either vestibular *or* proprioceptive coding of hip and ankle angles.

Conclusions

Differences of the responses to SS translation between both subject groups are surprisingly small. Reduced use of hip responses in AV subjects confirms previous findings [1]. Our model simulations suggest that AV subjects may successfully substitute vestibular body-space signals by proprioceptive body-foot signals for stance stabilization in the body's sagittal plane.

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BIOMECHANICAL RISK FACTORS OF GAIT IN BAREFOOT SHOES

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Introduction

There are many, sometimes contradictory, opinions on wearing barefoot shoes in the professional public, mostly in physicians and physiotherapists. The reason most often is the fear of possible injuries. This research should point to possible biomechanical risk factors of walking in barefoot shoes. The aim of this research was therefore to evaluate the differences of selected biomechanical parameters of the non-dominant lower limb during stance phase of gait cycle between individual types of shoes.

Methods

Research group included 21 subjects, thereof 9 men (mean age 27.2 ± 2.9 years, height 177.1 ± 7.2 cm, weight 77.0 ± 11.1 kg) and 12 women (mean age 32.7 ± 7.8 years, height 169.3 ± 7.4 cm, weight 64.0 ± 9.1 kg). The condition for the participation in this study was at least six-month-long experience of walking in barefoot shoes. Walking was provided in three types of „shoes“, barefoot, barefoot shoes and standardized running shoes. Kinematic parameters of gait were by kinematic 3D analysis of the system Qualisys Oqus 100 (Qualisys AB, Göteborg, Sweden) obtained. Kinetic parameters of gait were by two force platforms Kistler (Kistler 9286 AA, Switzerland) obtained. The shoe factor was statistically evaluated by ANOVA ($\alpha = 0.05$).

Results

The statistically significant difference was found in the vertical ground reaction force, where barefoot walking and walking in barefoot shoes showed a significantly lower initial vertical load ($p = 0.001$), conversely the second peak of the vertical ground reaction force was significantly higher ($p = 0.001$), always in comparison with walking in standardized running shoes. The propulsive force was significantly higher ($p = 0.001$), just as the mechanical performance of ankle joint was increased ($p < 0.05$) during barefoot walking and walking in barefoot shoes in comparison with walking in standardized running shoes.

Conclusions

This thesis refers to the fact, that there is some objective analogy between walking barefoot and walking in barefoot shoes in the kinetic parameters. Walking in barefoot shoes appears as more energy-intensive from the point of view of the ground reaction forces and ankle power. Barefoot shoes can be used therefore as a therapeutic "tool" for more effective use of the ligament-muscle ankle and foot complex. However, barefoot shoes need to be taken as a potential risk factor for injuries due to higher energy and motor control requirements during gait.

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ASSESSMENT OF POSTURAL STABILITY IN DEPRESSIVE PATIENTS USING ACCELEROMETER SENSORS

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Introduction

Postural control represents a complex process integrating several body systems, namely the sensory, musculoskeletal and central nervous [1]. Any factor which interferes with the components of postural control can disrupt the body balance control [2]. These factors include antidepressants that can cause a significant worsening of psychomotor abilities in depressive patients but also in healthy volunteers who have taken one dose of antidepressant [3]. Therefore, the purpose of the study was to investigate the effects of the psychomotor changes induced by depression, which can influence the maintenance of the human balance at the level of the central nervous system.

Methods

Fifteen healthy and fifteen depressive patients were included in our study aimed on the investigation of postural stability. Both groups consisted of nine men (mean age 44.1 ± 4.8) and six female (mean age 50.0 ± 8.4). Depressive patients with a diagnosis of unipolar disorder were treated with antidepressants with the same mechanism of action to increase serotonin activity on nerve synapses. The postural activity was monitored accelerometer device (Xsens Technologies B.V, Enschede, NL) with two sensors positioned at the level of the fifth lumbar (L5) and fourth thoracic (Th4) vertebra. Both groups were subjected to two accelerometric measurements within interval one week during their stable antidepressant treatment. Measurements of balance were performed in four tested conditions: stance on a firm surface with eyes opened (EO) or closed (EC) and a foam surface with eyes opened (FEO) or closed (FEC). We have evaluated the amplitude (A_{AP}, A_{ML}) and the velocity (V_{AP}, V_{ML}) of trunk tilts in the anterior-posterior and medial-lateral directions, the root mean square (RMS) and the total area (TA) of trunk tilts. Statistical processing of data was performed using Mann-Whitney U test.

Results

Using the lumbar accelerometer sensor (L5), we found an increased accelerometric parameters values and thus increased postural instability in depressive patients in compared to control group in the following accelerometric parameters: A_{AP}, RMS in posture conditions with altered somatosensory inputs (EC, FEO, FEC); A_{ML}, V_{AP}, V_{ML}, TA in all tested posture conditions (EO, EC, FEO, FEC) during the first and after a week of repeated measurement. At the higher thoracic level (Th4), we found a similar worsening of postural stability in depressive patients in compared to control group in the accelerometric parameters: A_{AP} in posture condition FEC during the first measurement; A_{ML} in posture condition EC during the first measurement and in FEC after a week of repeated measurement; V_{AP}, V_{ML}, TA in all tested posture conditions (EO, EC, FEO, FEC) during the first and after a week of repeated measurement.

Conclusions

We confirmed the deteriorated postural stability in depressive patients and wefound a high repeatability of measurements at weekly intervals.

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ADDING HAPTIC INPUT DURING WALKING IN SOMEONE WITH AN INCOMPLETE SPINAL CORD INJURY

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Introduction

Individuals with an incomplete spinal cord injury (iSCI) have a high chance of falling [1]. Adding sensory information in the form of haptic input may improve walking balance control in someone with an iSCI [2]. This research investigated the effect of adding haptic input during walking in individuals with an iSCI.

Methods

Participants with an iSCI and age- and sex-matched able-bodied (AB) participants walked 10 m normally (iSCIn = 14, ABn = 14) and, if possible, in tandem (iSCIn = 10, ABn = 14). Haptic input was added in 50% of trials by lightly (<1N) touching a railing at their side with their index finger. Kinematic data were used to calculate spatio-temporal gait measures and variability (SD), medio-lateral and anterior-posterior dynamic margins of stability (MOS_{ML}& MOS_{AP}) and their variability (MOS_{ML}_SD & MOS_{AP}_SD). RMANOVAs tested for the effect of haptic input and presence of iSCI (α=.05). Spearman's Rho was used to correlate cutaneous sense and proprioceptive ability of upper (UE) and lower (LE) extremities in the group with iSCI.

Results

There were no group x condition interactions. In normal walking, adding haptic input decreased stride velocity ($p<.001$), step width ($p = .002$), stride length ($p < .001$), MOS_{ML} ($p < .001$), MOS_{ML}_SD ($p < .001$), MOS_{AP} ($p < .001$), and MOS_{AP}_SD ($p < .001$) compared to walking without haptic input. Group differences included a larger step width SD ($p = .031$), and a smaller stride length ($p = .021$) and MOS_{AP}_SD ($p = .047$) in individuals with iSCI. UE cutaneous sense was correlated with stride length ($\rho = .480$, $p = .044$) and MOS_{AP} ($\rho = .483$, $p = .042$). In tandem walking, lightly touching a railing reduced stride velocity ($p = .015$) and MOS_{AP} ($p = .011$). Step width SD ($p = .014$) and MOS_{ML}_SD ($p = .005$) were larger in individuals with iSCI. UE proprioception was negatively correlated with step width ($\rho = -.769$, $p = .009$) and stride velocity ($\rho = -.653$, $p = .041$).

Conclusions

There was a similar effect of added haptic input for both groups. The reduced stride velocity suggests an increase in the attentional demands of lightly touching the railing while the reduced MOS variability suggests improved balance control. Sensory capabilities affected how individuals with iSCI used added haptic input.

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AGE-DEPENDENT EFFECT OF MENTAL FATIGUE ON STATIC BALANCE CONTROL

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Introduction

Mental fatigue is a psycho-physiological state experienced following prolonged demanding cognitive activity. Past research has shown experimentally-induced mental fatigue to influence gait in healthy younger adults [1] and healthy older adults under dual-task conditions [2]. However, it remains unclear whether mental fatigue influences the control of static upright stance, and whether this effect (if any) is exacerbated in old age. We therefore studied the control of balance in mentally fatigued younger and older adults. A possible interaction effect of mental fatigue and dual-tasking on balance was also investigated.

Methods

Balance was assessed in 20 healthy participants (10 younger, 21 ± 1 years; 10 older, 74 ± 6 years) at baseline and following 25 minutes of either the incongruent Stroop colour-word test (mental fatigue) or leisurely reading (control). The two conditions were presented in a counterbalanced order on separate days. Centre of pressure path length was recorded when standing still for 30 seconds. This test was also completed with a concurrent backward counting task (i.e. a dual-task).

Results

Under conditions of mental fatigue, centre of pressure path length was, on average, 8.5 cm greater than the control condition in older adults (grey line in Figure 1). However, this effect was not observed in younger adults (black line in Figure 1). This age-dependent effect of mental fatigue was not significantly modulated by dual-tasking.

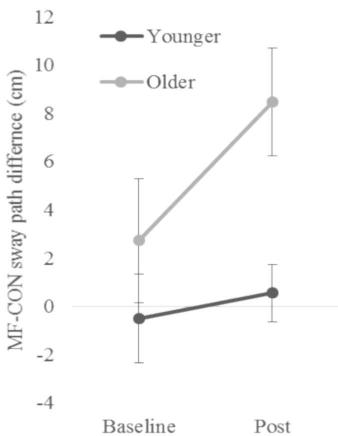

***Figure 1.** The effect of mental fatigue (MF) on sway path length in younger (black) and older (grey) adults. Values in the control (CON) condition have been subtracted from the MF condition to illustrate the MF-related effect. Mean ± standard error at baseline and post-conditioning is shown.*

Conclusions

Our findings show that mental fatigue impairs the control of static upright stance in only older adults. This is the first study to demonstrate an age-dependent effect of mental fatigue on static balance control. Whether due to everyday activities or symptomatic of a medical condition, mental fatigue may therefore contribute to poor balance and increased falls in older adults.

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OVERGROUND AND TREADMILL WALKING DIFFERENTLY AFFECT COGNITIVE PERFORMANCE

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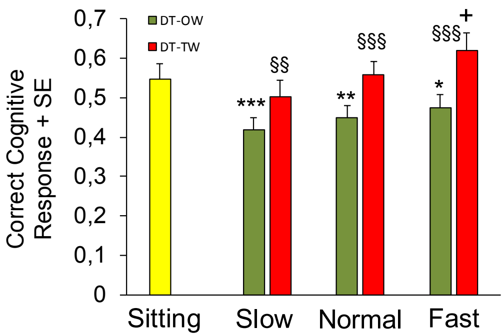
Introduction

A cognitive task performed during overground walking (OW) reduces gait speed [1]. Conversely, walking is an attention-demanding task that causes worsening of the cognitive performance compared to sitting [2]. Since treadmill walking (TW) facilitates the automaticity of gait [3], we have hypothesized that TW affects cognitive performance to a smaller extent than OW.

Methods

A total of 24 young adults were recruited. Each subject walked over ground over a 20-meter straight hallway at three different spontaneously chosen speeds (slow, normal and fast). Each condition was repeated 3 times in a Single Task (ST-OW) and a Dual Task (DT-OW) condition, in a randomized sequence. The DT consisted in backward counting by 7 starting from a different number (> 100) for each trial. For each subject, the average walking speeds (ST-OW) were imposed during the DT-TW condition. The correct cognitive response (CCR), calculated from the number of correct responses and mistakes, was compared between sitting, DT-OW, DT-TW.

Results



The three ST-OW speeds were significantly different. The corresponding DT-OW speeds were significantly slower, by 15% for both fast and normal respectively; slow speed was not reduced. Compared to sitting, *CCR* significantly decreased at all DT-OW (* in figure indicates comparison with sitting). The DT effect was more severe the slower the speed. CCR was much less affected by DT-TW (§ indicates comparison between DT-OW and DT-TW). Compared to sitting, *CCR* was not significantly decreased at slow speed and progressively improved from normal to fast speed, when it was significantly increased (+ indicates comparison with sitting).

Conclusions

Worsening of the cognitive performance DT-OW is more prominent at slower speed, in keeping with higher demand of attentional resources under this condition. Conversely, DT-TW reverses worsening of cognitive performance, more at fast than normal walking speed. The motorized treadmill entrainment enhances walking automaticity and likely decreases the cognitive burden of brain areas for walking control. Gait training, either by treadmill or sustained-speed over ground walking, can improve gait automaticity and diminish the cognitive cost of walking in patients with movement disorders [3].

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Measuring and understanding factors contributing to normal and abnormal control of body orientation during stance and gait

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Introduction

Appropriate methods that account for the closed-loop, feedback organization of balance control are increasingly being used to understand how humans control body orientation during stance and how abnormalities affect this control. This presentation summarizes methods we have used and gives examples that illustrate how vestibular loss (bilateral and unilateral) and mild traumatic brain injury (mTBI) influence the control of body orientation during stance. Additionally, we have recently extended our methodology to understand whether mechanisms used to control body orientation during gait are the same or different from those used during stance.

Methods

Orientation control was studied by applying continuous balance disturbances (surface or visual scene rotations at various amplitudes), measuring the evoked center-of-mass body sway, calculating frequency response functions (FRFs) that characterize stimulus-response dynamic behavior, and identifying a set of parameters of a control system model that accounts for the experimental FRFs. The parameters are functionally relevant in that they characterize the properties of important balance mechanisms including sensory integration (represented as a weighted summation of proprioceptive, vestibular, and visual cues) and sensory-to-motor transformation represented by a 'neural controller' that generates corrective torque to compensate for disturbances. These same analysis methods have been extended to investigate orientation control during gait using a stepping-in-place (SiP) protocol to determine how the same balance disturbances used to investigate stance affect body orientation during SiP. Our focus for SiP studies has been on disturbances that evoke medial-lateral body sway since active neural control is known to be critical to maintain stability in the frontal plane during gait.

Results

For stance control, sensory integration compensates for vestibular deficits by increasing reliance on orientation information from other sensory systems. In subjects with bilateral vestibular loss standing with eyes closed, measured sensory weights indicate 100% reliance on proprioception and, when vision is available, reduced flexibility in combining proprioceptive and visual cues. Although subjects with unilateral vestibular loss have one remaining functioning ear, they shift toward increased reliance on proprioception such that nearly all of them are distinguishable from controls. Results from one mTBI subject with chronic balance complaints demonstrate that an abnormal sensory-to-motor transformation mechanism can also be the cause of a balance disorder that is detectable and distinguishable from a sensory disorder. Lastly, SiP results reveal that body orientation is regulated by a mechanism that is the same as, or similar to that used for stance. However, orientation control parameters are adjusted for SiP such that there is less use of proprioception and much greater use of visual cues. Furthermore, neural controller and time delay parameters are altered to favor resonance behavior at the stepping frequency, possibly facilitating the oscillatory side-to-side motion associated with leg loading and unloading needed to allow stepping.

Conclusions

Methods are demonstrated that have the potential for improving our understanding of human balance control and have potential clinical applications for identifying the cause of balance disorders and possibly guiding rehabilitation.

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COORDINATION OF MULTIPLE MECHANISMS FOR BALANCE CONTROL DURING WALKING INTO ONE FUNCTIONAL RESPONSE

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Introduction

To maintain upright balance during walking, the central nervous system uses sensory information about the state of the moving body in space to detect threats to balance and generate an appropriate motor response to counteract them and keep the body stable. We have argued that there are three coordinated responses, available at different times throughout the gait cycle [1]. (i) During single stance, one can use the ankle musculature to pull on the body and generate a torque around the ankle joint. (ii) When taking a step, one can shift the foot placement relative to the center of mass (CoM), which changes how the gravitational force accelerates the body throughout the subsequent step. (iii) During double stance, one can shift weight between the two stance feet, by modulating the push-off force of the trailing limb against the ground. Here we test how these mechanisms are coordinated when disturbances occur at different points in the gait cycle.

Methods

Twenty healthy young adults walked on a self-paced treadmill immersed in a virtual reality environment projected onto a curved dome covering almost the complete field of vision. Subjects received binaural, bipolar galvanic vestibular stimulation (GVS) to induce the sensation of a lateral fall. Stimuli were triggered on heel-strikes of the right foot. GVS with 0.5mA amplitude and randomized polarity started with a randomized delay of 0, 150 or 450ms after each trigger and remained on for 600ms, with 6-8 strides washout between stimuli. We recorded full-body kinematics, ground reaction forces from the instrumented treadmill, and EMG from ten muscles along the legs.

Results

Subjects shifted their center of pressure in the direction of the perceived fall relative to the center of mass, starting approximately 250-350ms after stimulus onset. This onset time seems to be independent of the stimulus phase condition. In the 0 and 150ms delay conditions, this shift is initially generated by the right ankle during single stance, and then also by the foot placement and push-off mechanisms once they become available. In the 450ms delay condition, the time between stimulus onset and left heel-strike is too short to use the right ankle during single stance or to modulate the left foot placement. Instead, the left foot ankle is used to generate a functionally similar balance response.

Conclusions

Our results indicate responses that can transfer between the legs depending on the timing of the disturbance, suggesting a flexible organization that is not dependent on particular actuators or limbs.

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OCULAR TORSION RESPONSES TO ELECTRICAL VESTIBULAR STIMULATION IN VESTIBULAR SCHWANNOMA

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Introduction

The numerous health contraindications associated with caloric irrigation suggests a new vestibular test is required. Furthermore, many vestibular patients are too unstable to perform postural tests. Here we examine the viability of measuring eye movements evoked by electrical vestibular stimulation (EVS) to detect vestibular dysfunction in vestibular schwannoma patients (VS), who have a known unilateral deficiency.

Methods

EVS induces a sense of head roll around the naso-occipital axis [1], evoking compensatory torsional eye movements [2]. Here we determine if this technique can detect asymmetry between the ears. Participants received sinusoidal EVS (2 Hz ± 2 mA) in a monaural configuration. An infrared camera and illuminator were used to record torsional eye movements in darkness. The magnitude of the ocular response was determined for each ear, and an asymmetry ratio (AR) was calculated.

Results

We found there to be a difference in the gain of the response between healthy and diseased ears (AR: 10-50%), with the diseased ear's response being significantly attenuated ($T_{(24)} = 3.04$, $p < 0.05$). The patient group exhibited significantly greater asymmetry than control subjects ($T_{(48)} = 2.53$; $p < 0.05$). When participants were grouped according to tumour size, using Koos classification system [3], we found larger tumours resulted in smaller torsional responses leading to a greater asymmetry.

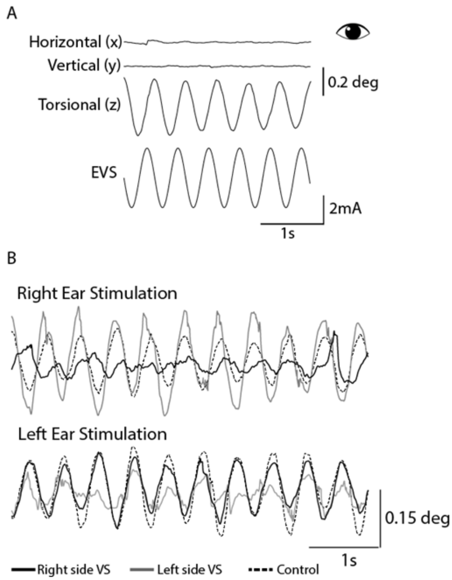

Figure 1. *3D eye movements evoked by EVS stimulation. A) EVS evokes eye movements primarily torsional in nature. B) A healthy individual (black dashed trace) shows similar response magnitude when either right or left ear is stimulated. However, the vestibular schwannoma patients showed reduced response magnitudes during ipsilesional ear stimulation (solid black and grey traces).*

Conclusions

These results provide a novel method for assessing vestibular function in patients for whom caloric testing is impossible, due to earwax or cardiac disease for example. The test was convenient, fast (~10 mins) and well tolerated by all patients, and successfully detected vestibular asymmetry. Future work will determine if changes in the 3D trajectory of the eye movement can be used to determine specific canal deficits.

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AUGMENTING BALANCE WITH TACTILE ROBOTIC FEEDBACK

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Introduction

Manual contact with an earth-fixed object can be as effective as vision in reducing postural sway, even when interaction forces are too low to offer significant mechanical support [1]. Conversely, contact with a moving object can *evoke* sway in a systematic fashion [2,3]. Here we determine if a moving haptic interface can be used to augment stability when its movement is time-locked to body sway, effectively altering the gain of haptic feedback.

Methods

Ten volunteers stood barefoot with their eyes closed and feet together, while grasping the end of a robotic manipulandum (MOOG haptic master) with their index finger and thumb, maintaining force below 1N. Body sway was sampled at 100Hz using a Polhemus Fastrak sensor attached to the back at the same height as the manipulandum. The manipulandum was driven in real-time using the body sway signal from the Fastrak sensor, thus allowing haptic feedback gain to be systematically manipulated. For example, when gain was set to +2, the haptic master moved in the same direction as body sway, but with double the amplitude. During negative gains it moved in the opposite direction. Postural sway was recorded for 1 minute periods of standing during the following haptic feedback gains: -2, -1, -0.5, -0.25, 0 (static), +0.25, +0.5, +1, +2. A no-contact condition was also included for comparison.

Results

There was a significant effect of haptic feedback gain upon body sway ($F_{(1,8)} = 47.4$, $p<0.001$; Figure 1). The +1 gain did not alter sway compared to no touch. For each person, we calculated the most stable gain condition; the median value was -0.25, being significantly different from zero ($t_{(13)} = 2.99$ $p = 0.011$).

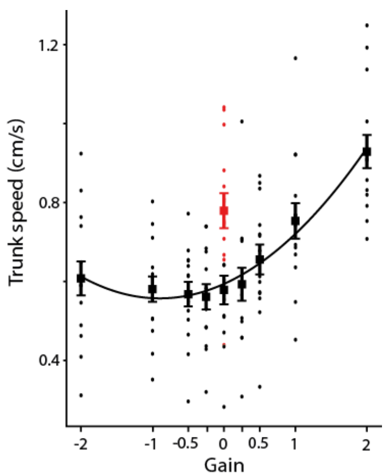

***Figure 1.** Effect of altered haptic feedback upon body sway. Mean trunk speed (+/- SEM) is shown for each condition of haptic feedback gain, with a quadratic fit. Individual subject values are shown by dots. The red/unconnected value indicates the no touch condition.*

Conclusions

We altered haptic feedback gain during light touch in standing. The setup is validated by the observation that +1 gain resulted in identical sway to no touch, effectively mimicking a freely-floating object, thus providing no feedback. Negative gains were most stabilizing, presumably because they are consistent with natural haptic feedback. Conversely, the +2 gain condition was actively *destabilizing*. This condition theoretically offers useful feedback despite being a reversal of natural gain, and future work will determine whether people can adapt to positive haptic gain. The most stable condition was -0.25, although it was only marginally better than a static object. This opens up the possibility of using enhanced haptic feedback to augment balance, particularly for people with balance difficulties.

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INDIVIDUAL DIFFERENCES IN INTRINSIC ANKLE STIFFNESS AND THE IMPLICATIONS FOR BODY SWAY

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Introduction

While controlling the unstable quiet standing position, the central nervous system actively modulates all the joints´ torques to complement its intrinsic stiffness [1–4]. The ankles are particularly important because they link the long vertical body with the short horizontal feet, the only body surface normally able to exert gravitational counteractive torques against the ground during standing. Previous research has reported a consistent large range of intrinsic ankle stiffness with measurements taken under the same conditions [1,3,5,6]. In the present study we investigate if these between-subject differences are significant enough to affect body sway responses. A general assumption is that people with intrinsically stiffer ankles should sway less when standing still and also when perturbed by ultra-slow tilting of the standing surface. Here we proposed a study to verify this relationship.

Methods

Intrinsic ankle stiffness of 20 participants standing freely on a rotating platform was estimated by recording ankle angle and torque responses to small, brief perturbations (0.1 & 0.7 deg; 140 ms). In a block of separate trials, the participants either stood quietly on a fixed platform or stood on the same platform when it was being moved by very slow sinusoidal tilts (0.2 & 0.4 deg amplitude at 0.1 Hz). This was used to provoke larger sway size to further verify the relationship between intrinsic stiffness and amount of sway. Sway was decomposed into two components, the spontaneous sway, or the natural random postural sway occurring during standing, and evoked sway, or the sway induced and synchronized with the movement of the platform.

Results

The results demonstrate the anticipated significant inverse correlation between intrinsic ankle stiffness and spontaneous sway, but there was no correlation between intrinsic ankle stiffness and evoked sway.

Conclusions

The implication is that the mechanisms related to short term stabilisation of upright standing are different from the process of defending a particular standing body position. Intrinsic ankle stiffness is useful for the former process but does not help the latter.

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NON-INVASIVE ELECTRICAL SPINAL NEUROMODULATION ENABLES INDEPENDENT STANDING AFTER PARALYSIS

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Introduction

Spinal cord injury (SCI) is a dramatic disorder resulting in paralysis and dysfunction of multiple physiological systems. Neuromodulation of spinal networks can improve motor control after SCI. The objectives of this study were to (1) determine whether individuals having been chronically paralyzed for more than a year can regain independent standing with the aid of non-invasive electrical spinal stimulation, and (2) investigate whether postural control can be further improved following repeated sessions of stand training.

Methods

Using a double-blind, balanced, within-subject cross-over, and “sham”-controlled study design, 15 individuals with chronic SCI of various severity received transcutaneous electrical spinal stimulation (TSS) over the lumbosacral area to regain standing without external assistance. The primary outcomes included the qualitative comparison of need of assistance on each knee and the hips during standing without and in the presence of stimulation in the same participants, as well as the quantitative measures, such as the level of each knee assistance and amount of time spent standing independently.

Results

None of the participants could stand unassisted without stimulation or in the presence of “sham” stimulation. With stimulation, however, all participants could maintain upright standing with minimum and some (n = 7) without any external assistance (Figure 1). Quality of balance control was practice-dependent, and improved with subsequent training sessions. Electrophysiological and functional properties of self-initiated postural adjustments during standing enabled by spinal stimulation, revealed functionally relevant responses that facilitated maintenance of upright standing with balanced posture.

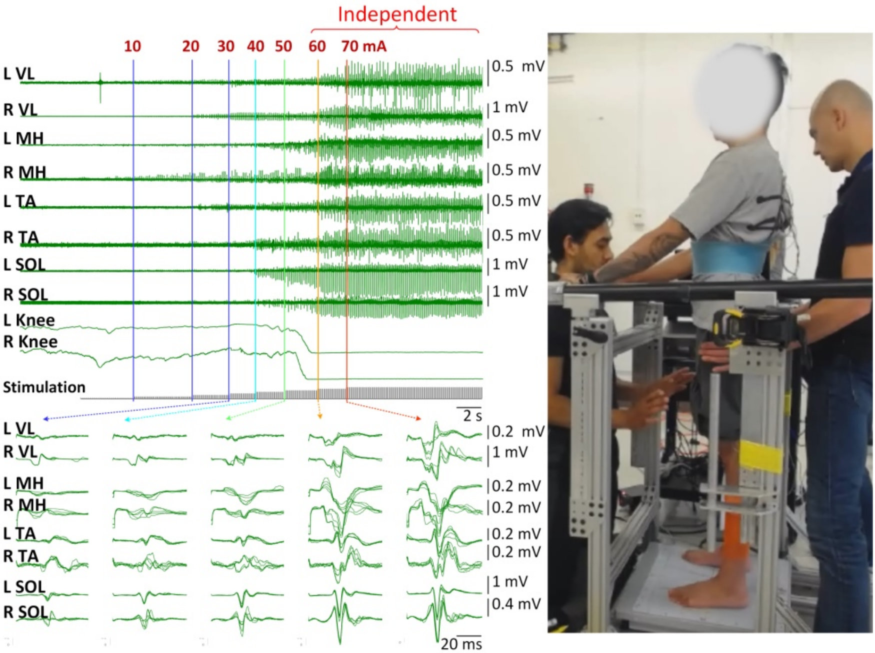

Figure 1. *During TSS delivered over the L1 at 15 Hz in participant with SCI (AIS A, T9), elevated lower leg muscle activity was observed, and at intensity of 60 mA, the trainers' support was not anymore.*

Conclusions

After years following complete paralysis, the ability of self-governing full weight-bearing standing was recovered by the enabling effect of non-invasive electrical neuromodulatory approach, and improved using repeated training sessions. The observed functional and electrophysiological effects were similar qualitatively and quantitatively to those seen in experiments with epidural stimulation. The physiological impact of our findings encompasses multiple functional systems that may contribute to the independence and quality of life in a broad population of individuals with SCI. The present data demonstrate that extensive neuroplastic changes of spinal and potentially supraspinal networks can occur using TSS administered in association with motor tasks.

Modulating gait asymmetry and motor switching with split-belt-treadmill in Parkinson's disease: feasibility of a study protocol and preliminary results

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Introduction

Freezing of gait (FOG) is a symptom of Parkinson's disease (PD) that is characterized through the inability to generate effective stepping despite the intention to walk [1], which leads to a high risk of falls. It is associated with asymmetric gait [2] and difficulty in motor switching [3]. Split-Belt treadmill (SBT) is a tool that potentially modulates both, asymmetry and switching from one to another motor program. The aim of this study is to investigate gait adaptations and transfer to overground walking of a single SBT training session and determine the most effective SBT condition.

Methods

This randomized controlled trial is currently conducted at the KU Leuven, Belgium and CAU Kiel, Germany. Sixty-four people with PD and FOG (PD+FOG) and 64 healthy controls (HC) will be randomly assigned into four 30-minutes (6x5min) intervention groups: A) Split-Belt ratio 3:4; B) Split-Belt ratio 1:2; C) Split-Belt changing ratios; D) Tied-Belt. For the Split-Belt condition the belt's velocity of the side with the longer step length will be reduced. The following tests will be conducted before (PRE) and after (POST) the training and after 24h (RET): Overground gait analysis under single and dual task (ST & DT) condition (auditory Stroop test), Split-Belt-Treadmill gait analysis, 1-minute 360° turning in place (ST & DT), postural sway analysis and cognitive assessment.

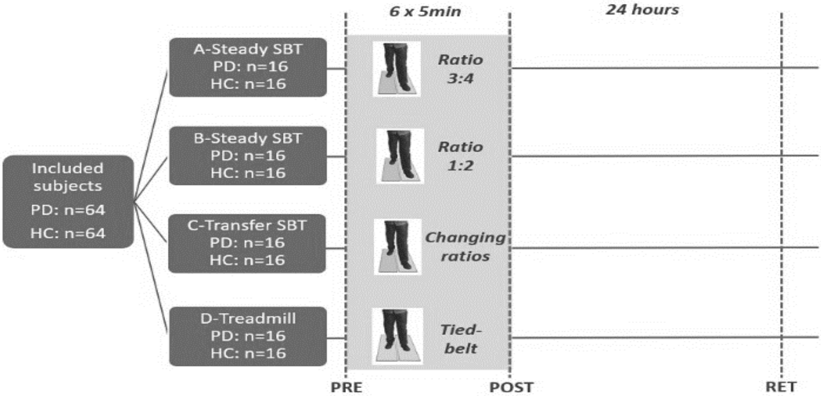

***Figure 1**. Study Protocol: Timepoints for assessment PRE, POST and RET are before, after and 24 hours after training session.*

Results

Walking on a SBT was safe for all included participants so far and no adverse events (e.g. falls) occurred during testing/training. So far 23 freezers and 9 healthy controls underwent the protocol. In 3 patients FOG episodes occurred during SBT walking. Due to the length of the protocol not all participants could finish the entire training session. Subjective measures to monitor fatigue and exertion are implemented in the protocol.

Conclusions

This implicit learning protocol was found to be safe for people with PD with freezing of gait. When conducting an extensive study protocol monitoring exertion is key to avoid bias due to fatigue. Preliminary results will be presented.

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CURVED WALKING: HOW TO COPE WITH THE EQUILIBRIUM CONSTRAINTS?

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Introduction

Postural constraints affecting the balance control system are minimal when walking straight. In curved walking, the brain organizes the movement taking into account not only the equilibrium constraints related to propulsion, but also those related to body orientation in space [1].

Methods

The talk summarizes previous and recent findings on curved walking, and suggests ways in which this task can be improved. Data will be reported concerning healthy subjects and Parkinsonian patients. The results reported were obtained by muscle vibration, EMG, optoelectronic cameras, sensorized insoles, rotating platform.

Results

Vibration and steering during walking. Unilateral axial muscle vibration administered during locomotion produces trajectory deviation, much as occurs on deliberately walking along curved trajectories or during podokinetic after-rotation. Vibration also affects vestibular-induced self-motion perception and produces appropriate placement of the feet, during both walking and stepping in place [2,3,4].
Medio-lateral torque for steering. At heel strike, the medio-lateral distance between center of mass and center of pressure of the foot external to the curved trajectory produces a gravity-driven torque that moves the body towards the inner part of the trajectory. Once the trunk passes over the foot, the center of pressure moves to the inner metatarsals and brakes the torque directed internally. Both feet behave functionally in the same way. Overall, a double push-pull mechanism exploits gravity during curved walking [5].
Curved walking in disorders of movement. Patients with Parkinson's disease have walking problems, more obvious during curved than linear trajectories [6]. However, integration of proprioception is preserved in these patients [7]. This can explain why patients learn to produce curved walking when faced with ad-hoc training by a rotating treadmill, and this capacity translates into improved over-ground walking along curved trajectories [8].

Conclusions

Curved walking offers an excellent opportunity to address the interaction of balance and gait.

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CONVERGENCE OF PODOKINETIC AFTER-ROTATION AND BODY TURNING RESPONSE TO AXIAL MUSCLE UNILATERAL VIBRATION DURING STEPPING IN PLACE

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Introduction

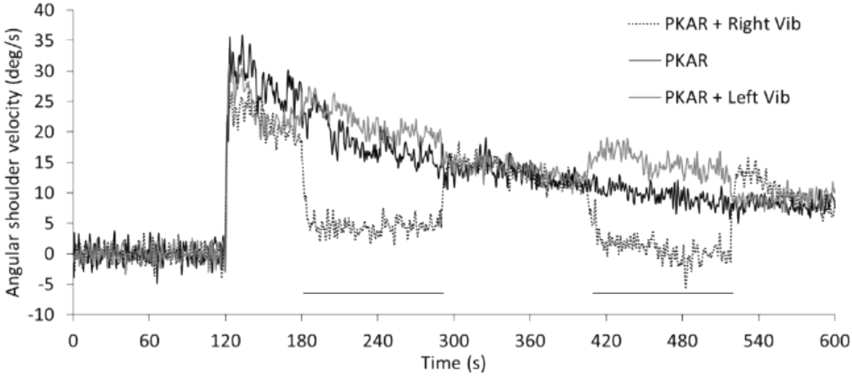
When subjects step in place eyes closed, they rarely maintain their initial straight-ahead orientation. Proprioception can incite steering behaviour. Unilateral vibration of neck muscles produces a rotation of the stepping body toward the opposite side [1]. Whole body rotation while stepping also occurs as after-effect of stepping on a circular treadmill (podokinetic after rotation, PKAR) [2]. The same outcome is the after-effect of simply stepping while deliberately rotating [3]. Here, we tested the hypothesis that PKAR is modulated by axial muscle vibration: if both interventions (PKAR and vibration) operate through a common pathway, facilitation or occlusion of the effects would occur depending on the stimulated side when both are administered concurrently.

Methods

Ten subjects participated in three sessions. In the 1st, subjects stepped in place eyes open on the center of a platform that rotated counter-clockwise 60°/s for 10 min (podokinetic stimulation). When platform was stopped, subjects continued stepping in place blindfolded (PKAR). In the 2nd and 3rd session, a vibratory stimulus (100 Hz) was administered to right or left paravertebral muscles at lumbar level during PKAR. We computed the angular body velocity from markers fixed to shoulders.

Results

During PKAR all subjects rotated clockwise. Decreased angular velocity was induced by right vibration. Conversely, when the vibration was administered to left, clockwise rotation velocity increased. The combined effect depended on the time at which vibration was administered during PKAR. When PKAR was intense, the effect of the vibration was smaller than when vibration was superimposed to a vanishing PKAR, as if sort of occlusion occurred when yaw rotation was running high, while vibration effect was no more counteracted by a weaker podokinetic after-rotation.



Conclusions

PKAR results from continuous asymmetric input from the muscles producing leg rotation, while axial muscle vibration elicits a related proprioceptive asymmetric input. Both conditioning procedures produce their effects through a common mechanism. We suggest that both stimulations would affect our straight ahead by combining their effects in an algebraic summation. In turn, the straight-ahead deviation would simply modulate the activity of those parts of the brain producing yaw rotation.

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ABNORMAL ANTICIPATORY POSTURAL ADJUSTMENTS IN PARKINSON'S DISEASE - CAUSE OR COMPENSATION FOR FREEZING OF GAIT?

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Introduction

Start hesitation or gait initiation failure, the inability to successfully transition from a standing posture to walking, is a common motor impairment in Parkinson's disease (PD) associated with freezing of gait (FOG) [1]. It has been shown that people with PD who have FOG show impaired postural control [2,3]. In this study, we investigated whether abnormal APAs contribute to the occurrence of start hesitation, or, alternatively, whether altered postural control might compensate for FOG.

Methods

Thirty-three people with PD with FOG (PD+FOG) (MDS-UPDRS-III: 44.2 (13.2); age: 69.2 (6.5)), 30 PD patients without FOG (PD-FOG) (MDS-UPDRS-III: 41.1 (10.1); age: 69.6 (8.5)) and 32 healthy control (HC) (age: 69.4 (6.8)) were tested. We analyzed postural sway in stance (30 sec) followed by gait initiation without and with a cognitive dual task (DT, consisting of serial subtraction by threes). Postural sway during stance, anticipatory postural adjustments (APA) and step kinematics were characterized with inertial measurement units (waist and shins) and muscle activity of the tensor fasciae latae (TFL), gastrocnemius and tibialis anterior muscles was captured with EMG recordings. Nine trials (of 190) were associated with FOG and analyzed separately.

Results

The three groups did not differ in age or gender and PD+FOG and PD-FOG did not differ in disease duration, MDS-UPDRS-III or Hoehn & Yahr scores ($p < 0.05$). PD+FOG and PD-FOG did not differ in size of their APAs when tested without the DT. In the DT condition, PD+FOG had significantly smaller medio-lateral (ML) and anterio-posterior (AP) APA amplitudes compared to PD-FOG and HC ($p < 0.01$). Within the PD+FOG, the ML size of APA (DT) was positively correlated with the severity of FOG (NFOG-Q) ($\rho = 0.477$, $p = 0.025$) and APAs were largest during freezing episodes. PD+FOG also had more TFL co-contraction during APAs.

Conclusions

People with PD with a history of FOG have smaller ML APAs (weight shifting) during gait initiation compared to PD−FOG and HC. However, start hesitation (FOG) is not caused by an inability to sufficiently displace the center of mass toward the stance leg because APAs were larger during trials with FOG and larger APAs were associated with worse FOG. We speculate that reducing the acceleration of the body center of mass with hip abductor co-contraction for APAs might be a compensatory strategy in PD+FOG, to address difficulty coupling postural adjustments and step initiation.

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RAMBLING-TREMBLING COP DECOMPOSITION AND SAMPLE ENTROPY IN FUNCTIONAL AND STATIC BALANCE OF BALLET DANCE EXPERTS

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Introduction

Classical dance is considered a type of physical activity that demands superior balance control and involves execution of static as well as complex chained dynamic choreographic figures. The standard force platforms balance measurements are often not sensitive enough to show differences between athletes and non-athletes. More advanced COP signal analysis is needed, therefore the use of rambling-trembling COP signal decomposition introduced by Zatsiorski and Duarte [1]. Dynamical structure of COP signal during a simple motor task like quiet standing, i.e. its regularity was found to be positively related to the amount of attention invested in postural control [2]. Regularity of COP trajectories was quantified by the sample entropy. Low values of entropy show more regularity in COP signal, and its high values signify less regularity in COP signal [3]. The purpose of this study was to examine the postural sway characteristics of the ballet dance experts in quiet standing and at their limits of stability.

Methods

The study was conducted on thirteen female ballet dancers with an average career span of 17 years and thirteen non-training females. The testing procedures involved standard force plate measurements. To gain better insight into the postural control processes we used the rambling-trembling and sample entropy analyses in the COP data processing. In addition to the range and velocity of COP, rambling and trembling, the sample entropy was analyzed as dependent variable.

Results

The main findings of the study showed professional dancers to have higher values of postural sway characteristics in comparison to the non-trainees while performing simple motor tasks (quiet standing). Also, higher values of the trembling component in the group of dancers during quiet standing and the inclined positions were observed. This might be a sign of higher capacity of the postural system to deal with postural instability in dancers.

Conclusions

Our results confirmed that the visual information is important in the process of postural control of dancers', which is proven by increased dislocations of the COP in the absence of visual feedback. The sample entropy results indicated more irregular characteristics of postural sway in ballet dancers representing more automated postural control.

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THE EFFECTS OF AGE AND STRENGTH ON ANKLE PROPRIOCEPTIVE ACUITY

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Introduction

Older adults are known to be at greater risk of falling. Ankle proprioception provides important sensory input for balance control. Therefore, a decline in ankle proprioceptive acuity may contribute to age related balance loss. Proprioception has been reported to be impaired in older adults [1], as well as people with muscle weakness [2]. However, it is unclear whether age associated reduction in proprioceptive acuity is primarily due to weaker muscles in older adults, or the result of another ageing process independent of strength.

Methods

Ankle proprioceptive acuity and leg strength were measured in 38 healthy adults aged 20-88 years old. A foot position matching task was used to provide a measure of ankle proprioceptive acuity. Subjects stood on motor-controlled foot plates capable of passively rotating the feet about the ankle (plantarflexion/dorsiflexion). With their eyes closed, the right foot was passively rotated randomly to one of seven ankle angles (target positions); 2, 4, 6^{o} plantarflexed/dorsiflexed, and neutral (0^{o}). Using a controller, the subjects passively moved their left foot to match their right foot position. The absolute difference between the foot positions (matching error) provided a measure of acuity. To measure lower leg strength, subjects sat on a bench with their right leg firmly clamped between a pad (placed behind the knee) and the floor. They then produced a series of maximum voluntary contractions, attempting to lift their heel and pushing up into the pad. The force generated was measured and the peak force was used to compare leg strength between subjects. Partial Least Squares Regression (PLSR) analysis was performed to model age and leg strength against matching error for each of the seven target positions.

Results

There was a significant relationship between age and leg strength, with strength declining with age. Across all subjects, matching error was lowest around the neutral foot position and became greater as the target foot position became more plantarflexed or more dorsiflexed. For plantarflexed foot positions, the PLSR models were unable to significantly predict matching error. However, when the target position was neutral or slightly dorsiflexed (2^{o}), the models were significant and age was the significant predictor, with matching error increasing with age. In contrast, for the more extreme dorsiflexed positions (4^{o} and 6^{o}), leg strength was the significant predictor of acuity, with matching error decreasing with greater strength.

Conclusions

Ankle proprioceptive acuity was best when the foot position was within a range of ankle angles associated with normal standing (~1-2^{o}) [3], suggesting ankle proprioception is more finely tuned within this range. In these positions, older adults had reduced ankle proprioceptive acuity, whilst strength had little influence. Therefore, age related decline in ankle proprioception could be an important contributor to impaired balance control in older adults, although the mechanism behind this remains unclear. In more extreme dorsiflexed foot positions, stronger subjects had better acuity. Therefore, the effect of muscle strength on proprioception is dependent on state of the muscle.

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POSTURAL STABILITY IN CHILDREN WITH FAULTY POSTURE – A PILOT STUDY

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Introduction
Efficient postural control is of fundamental importance for motor development in children. Early detection of postural deficits will facilitate the selection of the optimal physiotherapy intervention. The main aim of the study was posturographic assessment of quiet standing in children with faulty posture and in healthy children.

Methods
The study comprised of 5-6 years old children with faulty posture who had been diagnosed with neurodevelopmental disorders during infancy and healthy children with no history of postural control or movement deficits. Step initiation was performed on two seperate force platforms (AMTI Accugait) during different motor tasks, ie., with and without an obstacle, step-up and step-down trials. The stabilographic signal of center of foot pressure (COP) displacements was divided into two phases: phase 1 - quiet standing before step initiation, phase 2 - quiet standing after step.

Results
The two-way ANOVA revealed a group effect for rmsCOP in sagittal plane for phase 1 and 2. The Tukey post-hoc test showed that the means of rmsCOP in sagittal plane for phase 1 were significantly higher in children with faulty posture tested when stepping up onto a platform situated at a higher level in comparison to children with typical development ($p = 0.04$) (Figure 1).
In children with faulty posture, one-way ANOVA revealed a significant impact of testing conditions on rmsCOP for sagittal plane for phase 1 and 2. A Bonferroni correction confirmed significantly higher rmsCOP during quiet standing in the step-down trial compared to unperturbed transit for phase 1($p = 0.04$). Step-down rmsCOP was significantly higher compared to step-up rmsCOP for phase 2 ($p = 0.003$).

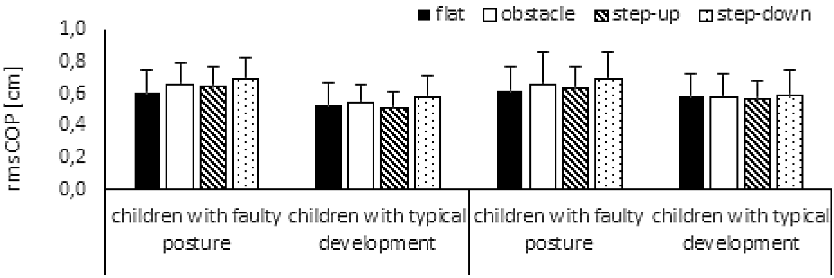

Figure 1. *Mean rmsCOP changes (±SD) in the sagittal (left) and frontal (right) planes during quiet standing before step initiation depending on testing conditions (phase 1).*

Conclusions

Unperturbed stepping on a flat surface between platforms was the easiest task for both groups which suggests that postural defects do not hamper postural control during simple motor tasks. The children with faulty posture had more difficulty controlling their postural sway in quiet standing than healthy children while stepping down. It is therefore well-justified to include stepping up and down tasks in targeted physiotherapy intervention in children with faulty posture.

RELATIONSHIP BETWEEN LOCAL DYNAMIC STABILITY AND FALL OCCURRENCE: COMPARISON OF PROSPECTIVE AND RETROSPECTIVE APPROACH

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Introduction

In the scientific literature many studies focused on fall risk would be found. Some of them used retrospective and some of them prospective approach. Although older people are usually able to recall falls in the past, fallers in retrospective approach would be considered rather as subjects, who already have fallen than subjects with increased future fall risk. It was showed that nonlinear methods of gait analysis, such as local dynamic stability, are able to distinguish between elderly fallers and non-fallers, however differences between prospective and retrospective evaluations of falls in one sample is unknown. The aim of this study was to assess differences in local dynamic stability between fallers and non-fallers using both prospective and retrospective approach.

Methods

A total of 131 elderly subjects participated in this study (mean age 70.8 ± 6.7 years). The 3D accelerometers were attached on the trunk near the L5 vertebra. From 150 strides the short-term and long-term Lyapunov exponents were calculated. Fall occurrence were recorded retrospectively (participants were asked for falls during 3 months before the measurement) and prospectively (1 year, phone call each two weeks). Comparison of groups was performed using Mann Whitney U test.

Results

Table 1 *Long-term and short-term Lyapunov exponents in fallers and non-fallers using both prospective and retrospective approach.*

Type of LE	Direction	Prospective				Retrospective				p level	
		N (n = 74)		F (n = 57)		N (n = 118)		F (n = 13)		Pro	Retro
		Mean	SD	Mean	SD	Mean	SD	Mean	SD		
Long-term	V	0.036	0.013	0.034	0.013	0.035	0.012	0.036	0.018	0.596	0.623
	ML	0.013	0.008	0.013	0.007	0.013	0.007	0.014	0.008	0.884	0.997
	AP	0.031	0.012	0.031	0.012	0.031	0.012	0.029	0.013	0.961	0.781
Short-term	V	0.69	0.14	0.72	0.17	0.69	0.14	0.79	0.21	0.334	**0.044**
	ML	0.91	0.19	0.97	0.14	0.93	0.18	0.99	0.13	**0.008**	0.225
	AP	0.69	0.14	0.73	0.17	0.70	0.14	0.80	0.22	0.092	**0.044**

Legend: LE – Lyapunov exponent, N – non-fallers, F – fallers, Pro – prospective approach, Retro – retrospective approach, V – vertical, ML – medial-lateral, AP – anterior-posterior.

Conclusions

Our results showed different findings in relationship between local dynamic stability and fall occurrence for prospective and retrospective approach. Future fallers compared to non-fallers had increased short-term Lyapunov exponent in medial-lateral direction. In retrospective approach fallers compared to non-fallers had significantly increased short-term Lyapunov exponent in vertical and anterior-posterior directions.

VISUALLY FIXATING OR TRACKING ANOTHER PERSON DECREASES BALANCE CONTROL IN YOUNG AND OLDER FEMALES WALKING IN A REAL-WORLD SCENARIO

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Introduction

Visually tracking a 2D target with smooth pursuits has been shown to increase trunk movement and step-width variability in young and older adults [1]. This was thought to result from more difficulty integrating retinal flow for postural control–like that shown during standing [2]. However, humans often fixate and track 3D objects, such as another standing or walking person [3]. Of interest is whether this will generate a similar balance response when compared to our previous investigation [1]. Since older adults typically have a reduced ability to process retinal flow, this could have important implications for older adults' postural control [4].

Methods

Ten young (age: 23.6 ± 3.4 years) and 10 older (71.0 ± 5.5years) healthy females walked overground during free gaze (FREE), and when fixating (STAT) or tracking (WALK) another person in an everyday-use waiting room. Balance was characterised by mediolateral (ML) sacrum acceleration SD (APDM, Opal). Gaze was assessed (Tobii Glasses 2) to ensure participants fixating and tracked the person. This was achieved by calculating RMS error between the observer gaze coordinates and the coordinates of the observed person.

Results

Consistent RMS gaze error suggested the participants fixated and tracked the person as instructed. There was a significant main effect of Sacrum SD ($F=_{2,36}$ = 8.6, $p < 0.01$). Post-hoc analysis showed decreased balance control when fixating a stationary ($p = 0.003$) and tracking a walking ($p = 0.027$) person compared to free gaze. The older adults exhibited reduced baseline stability, but the decrease caused by the visual tasks was not more profound than the younger adults.

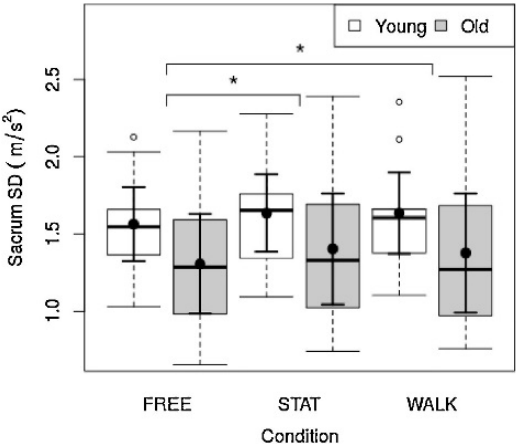

Figure 1. *ML Sacrum SD. Data are means ± CI, and lower and upper quartiles. *Significant difference between conditions.*

Conclusions

The decreased balance control when fixating on or tracking the observed person was likely due to more challenging conditions for interpreting retinal flow, which facilitated less reliable estimates of self-motion through vision. The older adults either processed retinal flow during the tasks as effectively as the younger adults, or they adopted a more rigid posture to facilitate visual stability, which masked any ageing effect.

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Light bulb characteristics affect stair descent in young adults

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Introduction

Adequate illumination is important for stair safety. In low light, for example, young adults increase foot clearance from the step edge, whereas older adults do not [1]. This smaller 'margin for error' may increase fall risk. Lighting has become particularly pertinent since incandescent bulbs were banned in many countries, resulting in households using energy efficient compact fluorescent light (CFL) bulbs. These can take minutes to reach full brightness, which may leave stairwells poorly lit. Light emitting diodes (LED) are also energy efficient, but reach full brightness immediately and could offer a better alternative. Yet, how CFL and LED bulbs affect stair safety has not previously been examined. The present study aimed to address this.

Methods

Stair tread illumination (lux) was recorded in a home environment (2.23m ceiling) from a low (50W, 630lm) and a high (103W, 1450lm) power CFL bulb. This yielded a warm-up curve for each bulb. Lux was also recorded from a low (40W, 470lm) and a high (100W, 1521 lm) power LED bulb at first turn-on. Power ratings for the CFL and LED bulbs were matched as closely as possible. Custom lighting then simulated these lux profiles, in addition to a 'bright' control, on an experimental staircase, which was descended by 8 young (age: 25.6 ± 5.0 years) healthy adults. Whole-body 3D kinematics (Vicon Mx) quantified mid-stair descent speed (DS), trunk vertical acceleration RMS (TA), and mean and variability of heel marker clearance (FC) from the step edges. A within-subject ANOVA examined lighting effects. Post-hoc analyses were t-tests with Bonferroni corrections (α=0.05).

Results

Participants adopted more cautious stair descent with CFL illumination as shown by reductions in DS and TA, and increases in FC (Table 1). There were no changes for FC variability.

***Table 1** Outcomes and lux recordings.*

Outcome	CFL Low (9–10+ lux, 4.11sec)	CFL high (19–20+ lux, 4.12sec)	LED low (35 lux)	LED high (112 lux)	Bright (350 lux)	RM ANOVA ($F_{4,28}$, p)
DS (m/s)	*0.47±0.04	*0.46±0.05	*0.48±0.05	0.51±0.06	0.49±0.06	2.90, 0.039
TA (m/s^2)	*0.27±0.08	*0.28±0.09	0.29±0.09	0.31±0.10	0.30±0.09	2.91, 0.039
FC mean (cm)	*6.22±0.50	5.81±0.72	5.83±0.56	5.98±0.58	5.56±0.59	2.72, 0.049
FC var (cm)	0.75±0.32	0.56±0.39	0.51±0.23	0.67±0.40	0.65±0.23	0.82, 0.52

N = 8 young adults. Data are mean ± SD. *Pairwise comparisons revealed significant difference from LED high and Bright ($p \leq 0.05$). '+' indicates increasing brightness as bulb warms from initial turn-on during average stair descent time.

Conclusions

This is the first study to show that the warm-up characteristics of CFL bulbs result in inadequate illumination as evidenced by cautious stair descent. High powered LED (100W) bulbs are thus preferable for stairwells, and particularly so for older adults who may not adapt well to lower light.

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AGE-RELATED CONTROL OF POSTURE & GAIT: EXPLORING ASSISTIVE METHODOLOGIES TOWARDS IMPROVING ELDERLY BALANCE

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Introduction

Falls are the leading cause of injury-related deaths and non-fatal, injury-related hospitalizations among elderly [1]. Approximately 1 in 4 Americans over 65 years old will experience falls. Further, 2.8 million elderly Americans are treated for fall-related injuries each year with 31 billion dollars in direct medical costs resulting from these injuries annually [2]. Indirect costs include the psychological fear of falling and a severe drop in (balance) confidence for everyday activities resulting in an overall decreased quality of life [3].
The purpose of this study was to examine the effects of utilizing targeted sensory training on the balance of participants aged 60 – 80 years old, while using either: 1) a distinctive NaviGAITor partial body weight support system or 2) non-mechanically supportive fingertip touch cues. Here we display our findings in healthy elderly that underwent training targeting base-of-support, somatosensory and visual inputs; even in relatively healthy elderly, balance could be improved with the use of sensory training.

Methods

All experiments for this study were held within the Center for Biomechanical & Rehabilitation Engineering (CBRE) at the University of the District of Columbia and the protocol was approved by the Institutional Review Board (#979744-1). We studied two training sets of participants: 1) those that used the NaviGAITor gantry system and 2) those that were allowed (light) fingertip touch cues. Participants completed a 6-week exercise routine, two 30 minute sessions/week. It is well known that inputs to the vestibular, visual, and somatosensory systems are used for balance. The training sessions progressively increased in difficulty, starting off with walking exercises, then moving on to various obstacle-training exercises using hard and soft foam (to modify foot somatosensory input) with eyes-open and eyes-closed (to modify visual inputs). Standard assessments conducted every 2 weeks (three Assessments total) included the Balance Error Scoring (BESS) and the Activities-Specific Balance Confidence (ABC) Scale. The Tekscan Forceplate Walkway was also used to acquire center-of-pressure (COP) data and assess changes.

Results

Improvements in BESS scores between the initial assessment (baseline at week 1) and the final assessment (at the completion of the training sessions) decreased in both NaviGAITor and fingertip touch groups. Improvements in balance confidence between the initial assessment and final assessment were observed in some participants, but not all; it is important to note that participants were blind to their initial ABC surveys. In comparing initial to final assessments, COP measures showed decreases in displacement and velocity, interpreted as an increase in stability.

Conclusions

Our observed decreases in BESS total score (e.g., decreases in the number of deviations from upright) and improvements seen in the COP displacement & velocity measures were interpreted as increased balance ability. This was an interesting finding in that, even healthy elderly without impairments showed improvements in balance resulting from the low-impact, moderate activities which incorporated sensory input training.

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SENSORIMOTOR INTEGRATION IN PRIMATES WITH VESTIBULAR DYSFUNCTION & APPLICABILITY TO HUMAN POSTURAL CONTROL

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Introduction

Quantitative animal models are critically needed for the investigation of rehabilitative balance therapies prior to, or in conjunction with, human clinical trials. Approximately 90 million Americans experience dizziness at least once within their lifetime; unfortunately, for many of these individuals balance deficits are permanent [1]. Further, approximately 8 million adults and 3.3 million children in the United States suffer from chronic balance disorders derived from severe peripheral vestibular dysfunction [2,3]. Yet, little is known regarding postural compensation mechanisms and rehabilitative treatments (e.g., vestibular implants) to aid balance in individuals suffering from vestibular impairments. We hypothesized that sensory reweighting (observed in humans as first shown in [4]) could be observed in non-human primates; here we describe a novel approach using sensorimotor integration modeling applied to primate postural control.

Methods

All experiments were conducted with the approval of the Massachusetts Eye and Ear Infirmary Institutional Animal Care and Use Committee and were in accordance with USDA guidelines. An adult female rhesus monkey was observed in the normal and mildly vestibular impaired states to collect the empirical data needed to test our sensorimotor integration model. We utilized pseudorandom, roll-tilt balance platform stimuli applied at 0.5, 1, 2, 4, 6, 8^{o} peak-to-peak platform amplitude, to perturb the posture of a rhesus monkey in normal and mild vestibular (equilibrium) loss states and collected 18-23 cycles for each stimulus amplitude. This type of stimulus had previously applied only to examine human postural control (e.g., [4]). The relationship between rhesus monkey trunk sway and platform roll-tilt was determined via platform stimulus–trunk response curves and transfer function results. A sensorimotor integration model was used to examine changes in sensory reliance which prevented the animal from falling off of the tilting platform.

Results

The normal monkey's stimulus–response and transfer results showed characteristics similar to those seen in humans (i.e., hindtrunk sway saturation for increasing stimulus amplitude was observed). A human feedback controller model was modified and implemented to test for sensory reweighting in a normal and mild vestibular-impaired primate. From our model, we were able to determine the animal’s neurophysiological model parameters for different levels of vestibular function and show that sensory reweighting was present.

Conclusions

Our observation that rhesus monkeys and humans have even remotely similar postural control motivates the further application of them as a model for studying the effects of vestibular dysfunction, as well as vestibular prosthesis-assisted states, on human postural control. This first-phase effort to model the balance control system in non-human primates is essential for future investigations toward the effects of invasive balance technologies on postural control in primates, and ultimately, humans.

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A RELATIONSHIP BETWEEN MUSCLE ACTIVITIES OF DOMINANT LOWER LIMB AND DISPLACEMENTS OF COM AND COP OVER STEPPING

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Introduction

The aim of the presented study was a determination of statistical relationship between muscle activities of dominant lower limb muscles occurring over stepping initiated from the given body position and: 1) the projection of the center of mass of the human body (COM) on the transverse plane in the medio-lateral direction (ML) and the anterior-posterior direction (AP); 2) the position of the center of pressure (COP) in ML and AP; 3) the position of COM along the longitudinal axis of the body (LA); 4) the difference of COM position of the whole body; 5) the difference of COP position. To analyze statistical models the multilinear regression method was applied.

Methods

Seven healthy males took part in this study elaborated on the base of the method presented in [1]. An initial position of the body was obtained from the central stance by keeping up both feet on the force plate and transferring the body weight: 1) in ML on the right foot; 2) in ML on the left foot; 3) on the both toes in the anterior direction; 4) on the both heels in the posterior direction; 5) on the toes of the right foot; 6) on the toes of the left foot; 7) on the heel of the right foot; 8) on the heel of the left foot. Kinematic data, COP positions and EMG data of four superficial muscles (Tibialis Anterior, Rectus Femoris, Gastrocnemius Medialis, Biceps Femoris) were recorded. The EMG data were processed by applying rms 250ms and mean 250ms algorithm. The statistical analysis was performed for: 1) differences of the COM projection on the transverse plane in ML and AP; 2) differences of the COP position in ML and AP; 3) differences of COM position calculated along LA; 4) the differences of COM position of the whole body; 5) the differences of COP position; 6) processed EMG data collected over initial position; 7) processed EMG data calculated as absolute differences between data collected during central stance and initial position. COM and COP data were treated as dependent variables thus the EMG data were treated as independent variables.

Results

To establish a statistical relationship the coefficient of determination R^2, correlation coefficient R and statistical significance p were calculated for 224 statistical models by using both rms 250ms and mean 250ms algorithms.

Conclusions

On the base of obtained results, we concluded that the method of signal processing has a big impact on establishing a statistical relationship between the chosen performance variable and EMG data treated as elemental variables (independent variables).

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THE POSTURAL STABILITY CHANGES OF ELITE ATHLETES AFTER ACL INJURY

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Introduction

Anterior Cruciate Ligament (ACL) tear is major concern in soccer [1]. Although ACL reconstruction and its postoperative rehabilitation are successfully performed, knee instability and neuromuscular control deficits are often prevalent at the time of return to play process [2].

Methods

National level male soccer players ($n = 16$, age 24.7 ± 3.9 years) volunteered in the study. Players performed postoperative rehabilitation protocol that had emphasis on enhancing postural stability (PS), muscular strength, and limb symmetry 6 times per week for 23 weeks. Static pressure measurements were obtained on a platform Footscan (RSscan International, Belgium). After the PS tests, following two tests were performed: bilateral narrow standing position (BS) with 2 levels of vision (eyes open and closed) for 30 seconds and single leg standing (SS) position test on injured and non-injured leg for 60 seconds. The tests were performed: (a) postoperatively, before rehabilitative intervention, five months (b), and 10 months (c) following ACL reconstruction. Mixed-design repeated measures (RM) ANOVA with Bonferroni's post hoc tests and partial eta square ($\eta p2$) were used for statistical assessment.

Results

The main factor (Time) revealed significant effect on PC both for BS ($F2,60 = 56.39$; $p < .01$, $\eta p2 = .65$) and SS ($F2,60 = 40.37$; $p < .01$, $\eta p2 = .57$). Post-hoc test revealed significant improvement of PC improvement after intervention (BSa = 151.34 ± 8.41 mm, BSb = 127.00 ± 6.56 mm, $p < .01$) as well as follow-up effect (BSb = 127.00 ± 6.56 mm, BSc = 109.63 ± 6.18 mm, $p < .01$). We found a significant interaction effect between observed factors (Time*Leg) within observed time ($F2,60 = 24.81$; $p < .01$, $\eta p2 = .45$). Participants significantly improved PC on injured leg (SSa = 1748.63 ± 78.81 mm, SSb = 1281.75 ± 62.70 mm, $p < .01$); however, postural control SSb was non-significant compared to SSc ($p > .05$).

Conclusions

The postoperative rehabilitation protocol demonstrated favorable postural control improvements following ACL reconstruction in elite male soccer players. Also, our findings indicated importance of continuous rehabilitation after 5 months following ACL reconstruction in order to eliminate asymmetry in postural control.

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DISCRIMINATORY ACCURACY OF BALANCE TESTS IMPROVES UNDER ALTERED STANCE SUPPORT CONDITIONS

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Introduction

Unstable conditions, in addition to unexpected postural perturbations, have the ability to differentiate between groups of physically active and sedentary adults as early as from 19 years of age [1]. Usually, a stance on a foam cushion, external perturbations from a platform either shifting in antero-posterior and medio-lateral direction or tilting toes up and down, and applying them directly to the body by pushing/pulling the trunk, shoulders or pelvis are used. Another, a novel alternative represents standing on a spring-supported platform. However, there is a lack of information on sensitivity of such testing method. Therefore, this study investigates discriminatory accuracy of balance tests under stable and unstable conditions across three age groups.

Methods

Participants were categorized by age into young adults (ages 19-24 years; n = 94), early middle-aged adults (ages 25-44 years; n = 69), and late middle-aged adults (ages 45-64 years; n = 71). They performed a series of two 30-second balance tests while standing on a stable force platform and an unstable spring-supported platform with eyes open (EO) and eyes closed (EC), respectively. Variables of postural sway were registered by using the FiTRO Sway Check system (FiTRONiC, Slovakia). The device consists of a triangular plate supported by 3 springs with coefficient of elasticity of 30 $N.mm^{-1}$. Shifting the center of mass in horizontal plane leads to changes of body weight distribution to the 3 corners of the platform. Force acting in each corner was calculated as a product of coefficient of elasticity of the spring used and vertical distance measured by means of a fine sensor. The analog signals were AD-converted and sampled by computer at the rate of 100 Hz. Calculations of instant center of pressure (COP) position was based on force distribution to the 3 corners of the platform. From instant values of COP position, a stabilographic curve was constructed. From such a curve, a mean COP velocity in mm/s from 30-second test as a parameter of postural sway was calculated. The discriminant ability of balance tests to differentiate between adults of various ages was assessed using the area under the ROC curve (AUC).

Results

Comparing with static balance tests with eyes open and eyes closed (AUC = 0.66, 95% CI = 0.62–0.69 and 0.70, 95% CI = 0.65–0.74, respectively), testing of postural stability while standing on a spring-supported platform increased significantly the discriminatory power (AUC = 0.82, 95% CI = 0.78–0.86; P = 0.006 and 0.87, 95% CI = 0.84–0.90; P = 0.009, respectively).

Conclusions

Unstable conditions improved the discriminatory accuracy of balance tests with both eyes open and eyes closed. Taking this finding into account, testing of postural stability on a spring-supported platform should be preferred over static balance tests in healthy young, early and late middle-aged adults.

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