ABSTRACTS

OF THE 6TH INTERNATIONAL

POSTURE SYMPOSIUM

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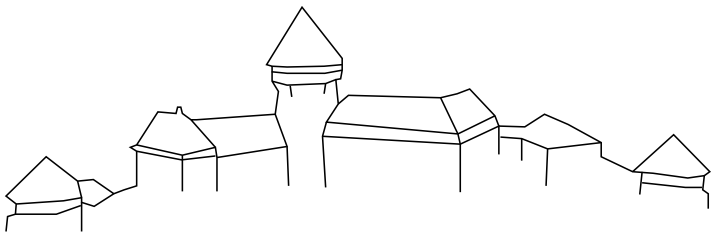
SMOLENICE CASTLE
SLOVAKIA
SEPTEMBER 15 - 18, 2011

INSTITUTE OF NORMAL AND PATHOLOGICAL PHYSIOLOGY
SLOVAK ACADEMY OF SCIENCES

6TH INTERNATIONAL
POSTURE SYMPOSIUM



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ABSTRACTS OF THE 6TH POSTURE SYMPOSIUM

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Smolenice Castle, Slovak Republic, September 15-18, 2011

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	Institute of Normal and Pathological Physiology
	Sienkiewiczova 1, Bratislava
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14:30	Transport by conference bus from Bratislava to Smolenice Castle
16:00	Registration and accommodation in Smolenice Castle
17:00	Opening Address:
	RNDr. O. Pecháňová, DrSc. (Slovakia), Director of Institute of Normal and Pathological Physiology
	Doc. PaedDr. O. Kyselovičová, PhD. (Slovakia), Vicedean of Faculty of Physical Education and Sports
17:15	Opening Keynote Lecture: *Prof. Dr. T. Mergner (Germany)*
	Sensory control of human posture and its modeling
18:15	End of session
19:00	**Welcome Reception**

Friday, September 16, 2011

7:15 - 8:00 **Breakfast**

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Chairmen: M. Latash, A. Nardone

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8:15 **The control of posture interferes with the learning of a mirror tracing task in older people**
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8:30 **Processing time of visual and tactile stabilizing inflow during stance**
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MC. Do (France)

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M. Beck, M. Marczak, J. Błaszczyk (Poland)

9:15 **Visual velocity information effects on human balancing of support surface tilts in a non visual-vestibular conflict situation**
L. Assländer, T. Mergner, A. Gollhofer (Germany)

9:30 **The role of foot architecture in postural control**
[1]WG. Wright, [2]YP. Ivanenko, [1]VS. Gurfinkel ([1]USA, [2]Italy)

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11:00 **Soleus activation determines step length**
[1]JL. Honeine, [2]M. Schieppati, [1]MC. Do ([1]France, [2]Italy)

11:15 **Lateral balance control during walking: can the extrapolated centre of mass model predict foot placement during lateral external perturbations?**
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11:30 **The initiation of locomotor-like movements by muscle vibration and passive limb manipulation in humans**
[1]E.Y. Shapkova, [2]M. Klous, [2]A.V. Terekhov, [2]M.L. Latash ([1]Russia, [2]USA)

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12:00 **Age-related differences in gaze behaviour during virtual walking**
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12:15 **An open customizable modular platform for analysis of human movement in the laboratory and outdoors**
M. Dozza, M. Idegren, T. Andersson (Sweden)

12:30 **Lunch**

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Chairmen: T. Mergner, R. Peterka

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E.E. Taylor, R.J. Peterka (USA)

14:15 **Intermittent control: how can we identify it?**
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16:45 **Does a fear of falling influence vestibular-evoked balance responses?**
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17:00 **Vestibular signals for orientation during self-generated head motion**
C.J. Osler, R.F. Reynolds (UK)

17:15 **Human physiological hand tremor results mainly from resonance which changes during slow voluntary movements**
M. Lakie, C.A. Vernooij, T.M. Osborne, R.F. Reynolds (UK)

17:30 **A decrease in short-range elastic stiffness causes a drop in physiological finger tremor frequency**
C. Vernooij, R.F. Reynolds, M. Lakie (UK)

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Saturday, September 17, 2011

7:15 - 8:00 **Breakfast**

Session 5 Postural impairments in clinical patients

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F.B. Horak, M. Mancini, A. Salarian, L. Holstrom (USA)

8:15 **Mild cognitive impairment as a predictor of falls in community-dwelling older people**
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8:30 **The eyes have it! A putative mechanism for facilitatory effects of visual cueing on turning in stroke survivors**
K. Hollands, P. van Vliet, G. Humphreys, M. Hollands (UK)

8:45 **Compelled body weight shift technique to facilitate rehabilitation of individuals with stroke**
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9:00 **The evaluation of postural control in children and youth diagnosed with Idiopathic Scoliosis**
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9:15 **New developments in EMG-based assessment of motor function and activity: implications for research and clinical practice**
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9:30 **Head extension effect on postural responses to galvanic vestibular stimulation**
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9:45 **Balance rehabilitation therapy by tongue tactile biofeedback in patients with degenerative cerebellar disease: preliminary results**
[1]O. Čakrt, [1]M. Vyhnálek, [1]K. Slabý, [1]T. Funda, [2]N. Vuillerme, [1]J. Jeřábek ([1]Czech Republic, [2]France)

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Chairmen: C. Maurer, P. Valkovič

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F.B. Horak, A. Salarian

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15:00 **Social activities**
(hiking in nearby Smolenice Castle, Red Stone visit – 10 €, Wine testing – 10 €)

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Sunday, September 18, 2011

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R. Psotta, J. Kokštejn, B. Hátlová (Czech Republic)

8:45 **Postural stability and visual feedback control of body position in physically active children and young individuals**
Z. Kováčiková, M. Štefanovský, E. Zemková (Slovakia)

9:00 **Balancing with an unstable object: the adaptation to a novel dynamic task**
[1]M. Furmanek, [2]C. Sutherland, [2]J. Frank, [1]G. Juras ([1]Poland, [2]Canada)

9:15 **The influence of active pronation and supination on the movement of the lower limbs and pelvis during gait**
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A. Cepková (Slovakia)

9:45 **Development and test of the DTP-3 noninvasive diagnostic system and its applications in clinical practice**
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12:00 **End of symposium**

12:15 **Lunch**

13:00 **Bus to Bratislava**

POSTERS

Friday, September 16, 2011

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P2 **Static balance and visual feedback control of body position in young and elderly individuals**
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P3 **Comparative study of two stabilometric platforms for the application in 3D biofeedback system**
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P4 **Differential roles of leg muscles during tandem stance**
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P5 **Are task performance and execution on a one-legged stance task influenced by postural threat?**
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P7 **Functional limit of stability influenced by wearing high heel shoes**
K. Bučková, O. Pinková, Z. Halická, J. Lobotková, F. Hlavačka (Slovakia)

P8 **Passive arm movements increase rhythmic activity in the hip joint under vibration**
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Saturday, September 17, 2011

P10 **Mobility Lab: an instrumented balance and gait system for clinicians**
[1]F.B. Horak, [1]M. Mancini, [1]A. Salarian, [1]P. Carlson-Kuhta, [2]L. Chiari, [3]K. Aminian, [1]L. Holmstrom, [1]J. McNames ([1]USA, [2]Italy, [3]Switzerland)

P11 **Methodologies to combine objective measures of mobility**
A. Salarian, M. Mancini, F.B. Horak (USA)

P12 **Ambulatory monitoring of assistive device use: novel approaches to assessing community ambulation in neurological populations**
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M. Janura, T. Dvořáková, Z. Svoboda, E. Krejčí (Czech Republic)

P18 **Gait deviation during combined visual-vestibular stimulation in roll**
S. Bardins, J. Claassen, E. Schneider, R. Kalla, R. Spiegel, M. Strupp, K. Jahn (Germany)

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E. Zemková (Slovakia)

P20 **Relationship between balance control and strength imbalances in elite junior soccer players**
T. Malý, F. Zahálka, L. Malá (Czech Republic)

EXHIBITORS

Delsys, Inc. DELSYS®

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ABSTRACTS

COMPELLED BODY WEIGHT SHIFT TECHNIQUE TO FACILITATE REHABILITATION OF INDIVIDUALS WITH STROKE

[1]AS. Aruin, [2]N. Rao, [2]A. Sharma, [2]G. Chaudhuri, [1]S. Mohapatra, [1]A. Eviota, [1]K. Ringquist, [1]SR. Muthukrishnan

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[2]Marianjoy Rehabilitation Hospital, Wheaton, IL, USA
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Introduction

Individuals with stroke-related hemiparesis commonly exhibit asymmetry in quasi-static standing postures and during functional movements [1, 2]. We developed a compelled body weight shift technique (CBWS) that helps individuals suffering from the effects of a stroke to improve weight bearing and stance symmetry [3]. The goal of this study was to assess the efficacy of CBWS in the rehabilitation of individuals with acute and chronic strokes.

Methods

Two groups of patients with acute stroke (n=11, UIC site) and chronic stroke (n=18, MRH) participated in the study. Each group was randomly divided into experimental and control subgroups. The experimental subgroups received conventional physical therapy combined with CBWS therapy (2 weeks for patients with acute stroke and six weeks for those with chronic stroke) and the control subgroups received only conventional therapy. CBWS involved a forced shift of body weight towards a person's affected side by means of a shoe insert that establishes a lift of the non-affected lower extremity. All the subjects underwent a battery of identical tests before the start of the rehabilitation intervention and following its completion. The chronic group was also tested three months after the end of treatment.

Results

After the intervention, weight bearing on the affected side increased in the experimental subgroup of acute patients and decreased in the control subgroup. Weight bearing increased in both the subgroups of chronic patients, however, the level of increase was larger in the experimental subgroup than in the control group. An increase in gait velocity was also observed after treatment.

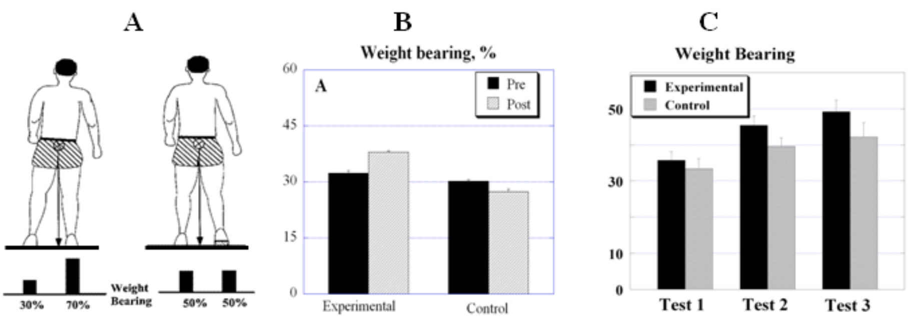

Figure 1. Schematic representation of the CWBS technique (A), changes in weigh bearing in the individuals with acute stroke (B) and chronic stroke (C).

Conclusions

The implementation of the CBWS therapy resulted in the improvement of symmetry in weight bearing and gait velocity in individuals with stroke. The achieved improvement was still present in individuals with chronic stroke four months after treatment.

References

[1] Bohannon RW, Larkin PA. Lower extremity weight bearing under various standing conditions in independently ambulatory patients with hemiparesis. *Phys Ther*. 65:1323-1325, 1985

[2] Rodriguez GM, Aruin AS. The effect of shoe wedges and lifts on symmetry of stance and weight bearing in hemiparetic individuals. *Arch Phys Med Rehabil*. 83:478-482, 2002

[3] Aruin AS et al. Compelled weightbearing in persons with hemiparesis following stroke: the effect of a lift insert and goal-directed balance exercise. *J Rehabil Res Dev*. 37: 65-72, 2000

VISUAL VELOCITY INFORMATION EFFECTS ON HUMAN BALANCING OF SUPPORT SURFACE TILTS IN A NON VISUAL-VESTIBULAR CONFLICT SITUATION

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Introduction
Intuitively, vision plays an important role in human stance control. Indeed, presence of visual space cues improves balancing upon external disturbances considerably. The identified sensory weighting factor of vision used in previous stance control models, however, is rather low (typically <0.2). We conceive that this is due to cognitive effects (e.g. subjects not 'trusting' the moving visual scene) and to the so-called visual vestibular conflict mechanism, both suppressing the visual contribution. We therefore reconsider the visual contribution to stance control, avoiding moving visual scenes. Here we reconsidered the effect of stroboscopic illumination (known to reduce or even eliminate visual velocity perception) on balancing of support surface tilts in a stationary visual environment. We compared effects on the upper body (trunk) with those on the lower body.
Methods
Six healthy subjects (3 men, 3 women; age 28±3 yrs) were presented with pseudorandom tilts of the support surface in the sagittal plane (frequency range 0.016-2.2 Hz). Motion of their trunk and legs were measured opto-electronically (Optotrak® 3020; Waterloo, Canada), and center of mass (COM) was calculated thereof. Center of pressure (COP) shifts were recorded by means of a force plate (Kistler® type 9286; Winterthur, Switzerland). The spectral characteristics of stimulus (tilt) and responses (motion of leg in space "LS" and trunk in space "TS", COP and COM shifts) were analyzed in terms of Bode histograms. Subjects were tested twice with 5 stimulus repetitions in each of the three following conditions: "eyes open" (OPEN), "eyes closed" (CLOSED) and "eyes open with stroboscopic illumination" (STROB; 4, 6, 8 and 10 Hz; 25 ms exposition time).
Results
The OPEN vs. CLOSED comparison essentially confirmed previous findings. LS and COM showed clearly larger excursion gain values in the CLOSED compared to the OPEN condition (factor approximately 1.5 in the mid-frequency-range). These excursions were roughly in phase with the tilts, apart from an increasing lag at higher frequencies, independent of the condition. Also TS showed larger excursions in the CLOSED as compared to the OPEN condition (by an almost constant gain factor across the frequency range tested). But its phase in the OPEN condition was counter to the tilt (low to mid frequency range), unlike in CLOSED. In the STROB condition, LS and COM gain and phase curves resembled closely those of the CLOSED condition. In contrast, the TS gain curve in STROB was improved considerably compared to the CLOSED condition, falling in between the gain curves observed in the OPEN and CLOSED conditions. Yet, the TS phase curve was not affected by STROB, but resembled that of the CLOSED condition.
Conclusions
Stability of COM during tilt compensation improved clearly when visual position plus velocity cues were made available (OPEN compared to CLOSED condition). This was not the case when only visual position cues were added (STROB condition). Thus the improvement of COM tilt compensation with eyes open owes mainly to visual velocity information. In contrast, trunk orientation with respect to the space vertical improves by comparable amounts through both position and velocity information.

THE EFFECTS OF 12 WEEKS OF RESISTANCE TRAINING UNDER STABLE AND UNSTABLE CONDITIONS ON BALANCE AND STRENGTH IN HANDBALL PLAYERS

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Introduction

Several authors have outlined the positive effects of instability resistance training in rehabilitation [1, 2] and prevention of injuries [3]. On the other hand, there are only scarce studies investigating the effect of combined balance and resistance training on athletic performance [4]. Therefore, the aim of the study was to evaluate: a) the effect of resistance training on stable surface, b) the effect of resistance training on unstable surface on balancing abilities and strength in handball players.

Methods

Twenty-four highly trained handball players (age 16 ± 1.8 years, height 178.2 ± 3.6 cm, weight 71.3 ± 4.2 kg) with no or minor experience with resistance training volunteered in this randomized, intervention study. The participants were divided into two groups. Group 1 started 6 weeks of resistance exercises (3 sets of 8 reps of chest presses and squats, respectively) performed on unstable surface followed by 6 weeks of resistance exercises performed on stable surface. Group 2 started on stable surface performing the same training for 6 weeks and then trained 6 weeks on unstable surface. Prior to, after 6 weeks, and after 12 weeks of training the 4 testing conditions of balance and the strength parameters were evaluated. Balancing abilities were assessed by standing on one leg on a Posturomed® with eyes open and eyes closed, respectively. Assessment of strength included three forms of jump, bounce-drop jump, countermovement jump, squat jumps and push-ups with countermovement.

Results

Results in all 4 testing conditions showed no significant improvements of balancing abilities and height of the squat and countermovement jump. However, ground contact time during the bounce-drop jumps improved significantly ($p<0.05$) after initial 6 weeks of training (from 0.277±0.021 s to 0.256±0.017 s) in the stable – unstable group. A highly significant improvement ($p<0.01$) was also found in the unstable – stable group (from 0.283±0.017 s to 0.252±0.014 s) prior to training 6^{th} week. However, from 6^{th} to 12^{th} week a significant longer ($p<0.05$) ground contact time was measured in the unstable – stable group. The push-ups with countermovement also improved significantly ($p<0.05$) in the stable – unstable group (baseline: 8.9±1.6 cm, 6^{th} week: 10.2±1.8 cm) whereas in the unstable – stable group, a significant improvement ($p<0.05$) from 9.4±1.4 cm at 6^{th} to 13.7±1.6 cm at 12^{th} week was found in the second part of the intervention. The drop jump index decreased significantly ($p<0.05$) from 6^{th} to 12^{th} week in the stable – unstable group (from 118.1±13.4 cm/s to 114.1±15.4 cm/s). However, its values increased significantly ($p<0.05$) in the unstable – stable group from 6^{th} (105.3±16.5 cm/s) to 12^{th} (124.7±18.9 cm/s) week.

Conclusions

Combined balance/resistance training is not more effective for the improvement of balancing and strength abilities than traditional strength training on stable surface for handball players who execute daily handball training. In addition, none of the two training regimes can be regarded superior for adolescents who also execute a daily handball training routine.

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PARAMETRIZATION OF POSTURAL SWAY

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Introduction
The use of the center of foot pressure (COP) in the clinical context is not new but no widespread consensus has emerged so far about the methods, techniques and interpretation of the data. There are intensive attempt to solve the problem by a search for adequate and reliable methods of sway parametrization that would reveal an unambiguous relationship between sway COP measures and quality of postural stability control.
Methods
In the search of a reliable postural stability index, COP time series have recorded in 23 young healthy subjects standing quiet. The participants completed five 60-s trials with eyes open and 5 with eyes closed. Their postural sway was assessed using 3 normalized sway parameters: the average velocity of the COP, the sway ratio [1] and sway directional indices defined as a ratio of a directional (AP, ML) to a total COP path length. The trajectories of the COP were determined by a force plate type 9281C (Kistler Group, Switzerland). All data were collected with a sampling frequency of 40 Hz. The COP time series were pre-filtered digitally with a law-pass filter (10 Hz cutoff frequency). A G-study was performed to estimate reliability coefficients [2]. All statistical analyses were performed using Statistica v. 6.0 software (StatSoft, USA).
Results
Results of the statistical analyses are summarized in Table 1. G-study revealed that the all normalized sway measures attained desirable reliability coefficient (higher than .86) with a single 60-s trial.

Table 1

Sway Measure		Eyes Open	Eyes Closed	P value
Path length [mm]	AP	799.0 ± 103.5	912.3 ± 128.5	0.000001
	ML	548.0 ± 63.3	631.8 ± 86.6	0.00001
Velocity [mm/s]	AP	13.3 ± 1.7	15.2 ± 2.1	0.000001
	ML	9.1 ± 1.1	10.5 ± 1.4	0.00001
Sway Ratio [mm/mm]	AP	4.39 ± 1.04	4.68 ± 1.23	0.004
	ML	3.1 ± 0.74	3.3 ± 0.82	0.03
Directional Index [mm/mm]	AP	0.74 ± 0.02	0.74 ± 0.03	NS
	ML	0.53 ± 0.02	0.52 ± 0.03	0.003

Conclusions
Analysis of the data involved comparison of the sway ratio and the COP directional indices in order to isolate the reliable parameters describing changes in the postural stability. The measures exhibited insensitivity to the length of sampled record and to the signal sampling frequency. This allows us to recommend them as the useful and reliable measures of the postural sway.

Keywords: *posture, stability, postural sway, sway ratio, sway directional index*

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COMPARATIVE STUDY OF TWO STABILOMETRIC PLATFORMS FOR THE APPLICATION IN 3D BIOFEEDBACK SYSTEM

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Introduction
According to permanently increasing incidence of brain damage, the rehabilitation of these patients becomes more and more important. Methods based on biological feedback are appropriately supplementing conventional rehabilitation procedures. Patients after brain damage often face situations (e.g. using escalators, orientation in city traffic) that can be possibly dangerous or even impossible to manage. For this reason we develop a stabilometric system with a set of 3D training scenes so that patients can experience these situations without any risk. Commonly used 2D gaming systems are not suitable for this purpose. The goal of this study is to compare two stabilometric platforms. One of them is an official medical device Synapsys Posturography System and the other is a developed device used in our rehabilitation system. We want to find out whether is it possible to use the developed device for objective evaluation of postural reactions.
Methods
We have examined the postural responses of 12 healthy adults (2 men, 10 women, average age 27 years) using always the same procedure on two stabilometric platforms. Half of them was examined first on the clinical platform and then on the experimental, the other half in reverse order. Each experiment consisted of 4 parts, each part took 60 seconds: stance on a firm surface with open and closed eyes, stance on a foam surface with open and closed eyes. We used the standard stance with feet under 30 degrees angle [1]. The postural response was characterized by displacement of the center of pressure. These stabilometric parameters were evaluated from the measured results: amplitudes of stabilogram, length and area of statokinesiogram, root mean square of statokinesiogram and amplitude spectra of stabilograms [2]. These parameters were statistically compared for both platforms. We also compared mechanical and technical parameters of the platforms, which are important for our application.
Results
Technical parameters of both platforms are quite similar (loading capacity, accuracy of measurement, sample rate). It was only found out that the smaller size of the experimental platform in the antero-posterior direction (316 mm) makes it difficult to examine patients with larger feet on the foam surface. There were only inconsiderable differences in measured results between the clinical (referential) device and the experimental one. Spectral analyses of the tests were cross-correlated. The influence of the measurement order was also insignificant.
Conclusions
According to results of the experiment we can declare the experimental device to be applicable in the rehabilitation of patients in 3D virtual reality for objective evaluation of postural reactions. The biggest problem is the smaller size of the device.

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BALANCE CONTROL ASYMMETRIES IN PARKINSON DISEASE: THEIR RELATIONSHIP WITH CLINICAL OUTCOME VALUES AND FREEZING OF GAIT

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Introduction
Parkinson's disease (PD) is typically an asymmetrical disease; motor symptoms usually start on one side of the body and, throughout the course of the disease, this side remains most prominently affected. Balance control can be asymmetrical in PD patients [1, 3]. That is, one leg is contributing more to body stability than the other leg. However, not all patients show this asymmetry. This raises the question whether there is a relationship between asymmetrical balance control and clinical phenotypes of PD, such as for example Freezing of Gait (FoG). Indeed, it has been shown that FoG is related to asymmetries in gait [2]. To date, it is unknown what extent asymmetrical balance control is a clinically relevant symptom in PD (i.e. is asymmetrical balance control common in PD, is it related to FoG and to actual falls or fear of falling?). Therefore, we investigated asymmetries in balance control and their relation to disease severity, FoG and history of falls in PD patients.
Methods
Twenty participants with idiopathic PD (OFF medication, 9 FoG, 11 nFoG (no freezing), 6 female, mean age: 63, std: 8) and nine healthy aged matched controls (2 female, mean age: 65, std: 5) were asked to maintain their balance without moving their feet, while standing still and during continuous random platform movements and continuous random force perturbations in the forward-backward direction. Body sway angle and the reactive forces of each foot were measured with a VICON system and an AMTI dual forceplate, respectively. These measurements yielded the Frequency Response Function (FRF) of the stabilizing mechanisms, which expresses the amount and timing of the generated corrective torque in response to sway at the specified frequencies. The FRFs were used to calculate the relative contribution of each ankle and hip joint to the total amount of generated corrective torque to resist the perturbations. In addition, the Unified Parkinson Disease Rating Scale (UPDRS), FoG, fall risk, fear of falling, 10 meter walk, Timed Up and Go (TUG) were evaluated.
Results
Using the responses of the healthy controls, the 99% confidence interval of balance control asymmetry for the ankle and hip joint was determined. Thirteen of the 20 patients were outside the normal values. The ankle joint was more affected than the hip joint. No significant relationship with UPDRS, FoG, fall risk, fear of falling or 10m walk was found. However, there was a trend towards a relationship with the TUG ($p=0.07$); that is asymmetrical patients were slower.
Conclusions
Balance control is asymmetrical in most patients, but this is not related to fall risk or fear of falling in PD. This finding suggests that current clinical outcome values are not sensitive to balance control asymmetries. However, the relationship with the TUG highlights the importance of balance control asymmetries for postural instability. FoG cannot be detected during feet in place balance responses, as balance control asymmetries were not associated with FoG, contrary to gait asymmetries [2].

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POSTURAL REACTIONS ARE DIFFERENT IN PARKINSON'S DISEASE AND PSP

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Introduction
Patients with Parkinson's disease (PD) as well as patients with Progressive supranuclear palsy (PSP) can have severe postural deficits and can experience frequent falls. In both diseases brainstem nuclei degenerate and these postural symptoms are not levodopa-sensitive. Thus it can be assumed that the mechanisms leading to postural deficits in these diseases may be the same. However, this has not been investigated up to now.
Methods
We applied two postural tests to a group of PD patients (n=18), PSP patients (n=21) and healthy control subjects (n=22), namely neck vibration and weight lifting. Both tasks were performed while the subjects were standing on a force measuring platform and postural reactions were measured with this device (coordinates of the center of pressure). Neck vibration was achieved with two small DC-motors with eccentric weights attached to the posterior neck muscles of the subject. Motors were both activated for 2 s and switched off for 3 s. This cycle was repeated 20 times with open eyes and 20 times with closed eyes and posturographic measurements were averaged time-locked to the onset of vibration. Weight lifting was done with a 1 kg dumbbell which the subject held in his/her right hand and had to lift it with his/her outstretched arm every 3-4 s. These lifts were performed 20 times with open eyes and 20 times with closed eyes.
Results
Neck vibration caused anterior body sway which was seem as an upward movements of the signals of the platform in saggital direction. This was initiated by a preceding small backward shift of the force vector while subjects were shifting their weight to the heel to initiate the body displacement in the anterior direction. Whereas this general (normal) pattern was preserved in both patient groups, PD patients showed a significantly higher amplitude of anterior body sway in comparison to normals and PSP patients. PSP patients were not different from normals. During weight lift, all subjects relocated their center of pressure anteriorly to stabilize posture with the weight held in front of them. PD patients reacted faster and the amplitude of their center of pressure movement was enlarged as compared with healthy subjects and PSP patients.
Conclusions
As a conclusion, we found that elementary postural strategies are preserved in PSP and PD. Whereas the amplitude of the postural reactions was normal in PSP, this was exaggerated in PD. Thus the mechanisms leading to postural impairment may be different in these two groups. However, as there was no difference between the results of normals and PSP patients, these tests seem not qualified to describe the pathophysiology of postural deficits in PSP. This may probably be possible by applying dynamic postural measurements.

FUNCTIONAL LIMIT OF STABILITY INFLUENCED BY WEARING HIGH HEEL SHOES

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Introduction

One way how to quantify postural stability is by measuring the limits of stability. The limits of stability can be defined, under dynamic conditions, as the maximum displacement of the centre of body mass during a feet-in-place response to external postural perturbations that can be controlled without a fall or a step [1]. Limits of stability, quantified by the maximum voluntary inclined posture may be considered as functional limits of stability, since they are influenced by subjective perception, internal postural control abilities and environmental factors [2]. To investigate limits of stability in the absence of external perturbations, the maximum voluntary inclined posture can be used [3].

Methods

In the study participated 25 young healthy women (average age 23.2 ± 2.1 years, average height 169.1 ± 6.6 cm, average weight 60.1 ± 6.9 kg). Subjects stood on force platform. Two dual-axis accelerometers (ADXL204) were situated on the fifth lumbar (L5) and the fourth thoracic (Th4) vertebra. Participants were instructed to make a maximal voluntary inclination after hearing sound signal (second sec after trial start) and persist in this position till hearing next sound signal (trial end). Inclination was performed in forward direction, using ankle strategy. Each trial lasted 10s and was repeated 3 times, under 4 conditions: eyes open - barefoot (EO_BF), eyes closed - barefoot (EC_BF), eyes open - high heels (EO_HH), eyes closed - high heels (EC_HH). We evaluated maximal amplitude and velocity of the inclinations. Analysis of variance with 2-way repeated measures was used as a statistic method.

Results

The results showed that maximal forward leaning was significantly smaller in conditions with high heels. In situation EO_HH was recorded 42% decrease of amplitude of CoP displacement and in EC_HH 38% decrease of amplitude of CoP displacement. In L5 and Th4 levels was recorded also significant decrease of amplitude ($p<0.001$) in maximal forward leaning, in situations with eyes either open or closed. In forward direction velocity of CoP responses was significantly reduced by 35% in EO_HH ($p<0.001$) and by 23% in EC_HH ($p<0.05$) conditions. In L5 and Th4 levels also significant decrease of velocity ($p<0.001$) was recorded, in situations with eyes open and the same with closed.

Conclusions

The present study showed that the functional limit of stability in forward direction is influenced by wearing high heel shoes. We consider that decrease of amplitude and velocity of CoP displacement and body tilts is a compensatory mechanism to maintain posture stability. The decline of functional limits of stability could leads to higher risk of falls and injures.

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CONTRASTING EFFECTS OF DBS AND LEVODOPA ON POSTURE CONTROL

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Introduction

The extent to which different types of postural control share common central path-ways may be inferred by the effects of loss of the neurotransmitter, dopamine, from Parkinson's disease (PD) and the effects of treatment for PD: dopamine replacement or deep brain stimulation (DBS) in the basal ganglia output nuclei. If PD, dopamine and DBS have similar effects on neural control of automatic postural responses (APR), anticipatory postural adjustments (APA) and sway in quiet stance. This would support the hypothesis of common central pathways for different types of postural control. However, we hypothesized that different types of postural control depend upon different neural pathways shown by different responsiveness to dopamine and DBS.

Methods

Twenty-nine PD subjects and 24 age-matched healthy control subjects were tested before and 6 months after DBS surgery (randomized to STN or GPi stimulation site). Subjects stood with each foot on a separate force plate and completed tasks to evaluate APRs to forward surface translations, APAs prior to step or rise to toes and sway during quiet stance. Postural stability during APRs was quantified as the difference between center of pressure (COP) and center of body mass during APRs, APAs quantified from peak lateral or anterior-posterior COP displacement during APAs, and as the area, velocity and frequency of sway during quiet stance. Before DBS surgery, subjects were tested *OFF* (no PD medication overnight) and ON medication (*DOPA*). Post-surgery, subjects were tested: OFF medication and DBS (*OFFOFF*), ON medication (*DOPA*), ON DBS (*DBS*), and ON medication and DBS (*BOTH*).

Results

Prior to surgery, subjects with PD showed significant postural instability in response to perturbations, reduced amplitudes of their APAs and increase postural sway area and velocity in stance. Levodopa did not improve postural instability in response to perturbations, improved amplitude of APAs, but worsened postural sway during stance. After DBS surgery, APRs in response to perturbations and APA magnitude prior to stepping or rise-to-toes were farther from normal than before surgery. In contrast, after DBS surgery, postural sway in stance was closer to normal. Furthermore, when the DBS was turned on there was some improvement in APRs compared to the *OFFOFF* condition, but there was no effect on APAs or sway.

Discussion

The benefits and impairments of different types of postural control by levodopa and DBS suggest different central neural pathways for control of postural responses, APAs and postural sway. In addition, unlike other aspects of motor control that are affected similarly by DOPA and DBS, APAs are increased by DOPA but decreased by DBS, suggesting either a uniquely negative effects of chronic DBS or a lesion effect of the neurosurgery on APA control.

Keywords: *posture, balance, Parkinson's disease*

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PHYSICAL FITNESS AND POSTURE OF STUDENTS OF UNIVERSITY

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Introduction

Dynamics of changes in the way of life increases the demand for social adaptability of humans to the changing conditions of living. As a result, the neuropsychological stress is increasing and the necessity of physical activity is decreasing. As an example of this process can be taken the transition to the university studies: psychological stress is increasing, the demand for activity and physical exertion is being reduced. Sedentary lifestyle is widespread. Physical education is in many cases the only one physical activity during their studies. In terms of comprehensive development of students, the assessment of the state of physical development and their physical fitness are of great importance. As a proof of this fact, many research works [1, 2, 3] can be cited, in which the authors evaluate the dynamic level of physical fitness and physical development students of university.

Methods

The object of investigation was a set of students from the FME STU Bratislava. 4 measurements: n = 320 (A) 2.sem. ac.year 2008/09, n = 238 (B) 1.sem. ac.year 2009/10, n = 264 (C) 2.sem. ac.year 2009/10, n = 194 (D) 1.sem. ac.year 2010/11. The testing was realized during a class of Physical education, at the beginning of the semester. It was chosen the Physical fitness called UNIFITTEST and, as the correct posture, the one defined by MATTHIAS TEST (Fig. 1). Students were asked to take the following posture: standing erect with legs and shoulder slightly apart, arms forward, head in the extension of trunk. After one minute, we evaluated their postures. As it is shown in the Fig.1, the correct posture was evaluated as "1" and the incorrect one as "0".

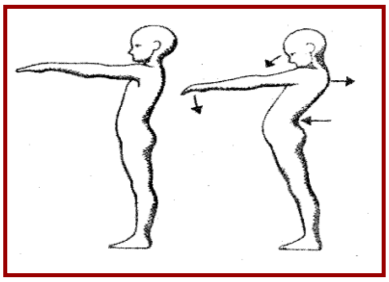
Figure 1. Test by Mattias

Results

Results of UNIFITTEST: lie-set60s was 40 to 42 repetitions, jumping from place to achieve 215 cm, in pull-ups made from 5 to 7 bends. It means that the students achieved average values. We can say that in almost all measurements of physical fitness, we found that students with better posture (1) reached also better values than the students with poor posture (0). Only in some indicators the situation was opposite. In most cases, the students with the correct posture (1) had lower value in circumferential than the students with poor posture (0), $p < 0.01$. Students with the correct posture (1) reached lower values in the most peripheral rates in $p < 0.01$, which also had significantly lower weight at the students (1) as (0) $p < 0.01$.

Conclusions

During the study, there has been documented some individual measurements, indicating for some students no significant changes in tests. We found that students belong to a group of people, with almost no risk of the cardiovascular diseases and diseases resulting from obesity. We can talk about health-oriented physical activity for students. It means that their current status in colleges does not get worse, it is rather stable. To conclude, the hours of compulsory physical education are an important factor in influencing the quality of human life. The students with better posture were more resistant to all types of stress and they were also more balanced.

Keywords: *Mattias test, UNIFITTEST (6-60)*

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EFFECTS OF MANIPULATING ANXIETY ON STEPPING BEHAVIOUR DURING ADAPTIVE LOCOMOTION

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Introduction

Looking (directing gaze) in the right place at the right time is crucial for safe walking, and there are age-related changes to gaze behaviour which increase falls-risk in older adults. For example, older adults at a high risk of falling tend to look away from a target they are still stepping towards in order to look at potential obstacles ahead [1, 2]. This early gaze transfer impairs the accuracy of stepping and increases the likelihood of tripping. We have provided evidence that this maladaptive gaze behaviour is associated with increased anxiety [3]. However, the direction of this association remains unclear: it could be that anxiety is causing inappropriate gaze behaviour and stepping problems, but it is also conceivable that anxiety increases as a result of poor stepping performance. To test the former possibility, the present study used social evaluative threat (SET) [4] and differing task complexities to experimentally manipulate anxiety. It was hypothesized that increased anxiety would results in increased variability in foot placement.

Methods

Eight young adults (mean age 18.9 ± 0.4 years) walked obstacle courses of varying complexities under both control and judged (SET) conditions in separate sessions. The courses consisted of: 1) a stepping target only; 2) a target followed by a far obstacle; 3) a target followed by a near obstacle, and; 4) a target followed by both obstacles. Salivary α-amylase and heart rate were used as an indicator of physiological anxiety, and the State Anxiety Inventory (SAI) was used to assess self-reported anxiety. Full body kinematics were recorded using a Vicon MX motion analysis system.

Results

Paired t-tests revealed that SET successfully increased all indicators of anxiety; i.e. α-amylase (17.7 ± 9.3 to 44.4 ± 13.4 U/mL, $t_{(31)}$=-2.2, p<.05), change in heart rate compared to baseline (-2.0 ± 3.9 to 2.9 ± 5.8 bpm, $t_{(31)}$=-3.5, p<.001) and SAI (6.6 ± 1.6 to 7.9 ± 1.7, $t_{(24)}$=3.7, p<.001), comparing control and SET, respectively. Further, repeated-measures ANOVA revealed a significant interaction effect between task complexity and SET in anterior/posterior (A/P) foot placement variability ($F_{(3, 21)}$ = 3.4, p<.05), such that participants in the SET condition showed greater A/P foot placement variability, but only in the third task condition.

Conclusions

The results present social evaluative threat as a novel paradigm to experimentally manipulate anxiety during a short precision stepping course. The results also demonstrate a causal link between anxiety and impaired stepping performance during adaptive locomotion. In young adults, the effects of anxiety on stepping became apparent only with increasingly complex stepping tasks. Future studies will extend this paradigm to the study of older adults and will include eye movement measurements in order to further explore the relationship between anxiety, gaze behaviour and falls-risk in this population.

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BALANCE REHABILITATION THERAPY BY TONGUE TACTILE BIOFEEDBACK IN PATIENTS WITH DEGENERATIVE CEREBELLAR DISEASE: PRELIMINARY RESULTS

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Introduction

Cerebellar damage typically results in ataxia and can be caused by stroke, tumor, or some degenerative diseases. Since few pharmacological options are available, most treatments rely heavily on rehabilitation therapy [1]. A possible way to improve balance is the use of a biofeedback system in balance prosthesis. Tyler et al. [2] developed a head position-based, tongue-placed biofeedback system whose underlying principle is to transmit artificially sensed head orientation/motion with respect to gravitational vertical along anteroposterior and mediolateral axes through electrotactile stimulation of the tongue. The aim of present study was assessing the effectiveness of a balance rehabilitation program using this biofeedback system in patients suffering from progressive ataxia due to cerebellar degeneration.

Methods

Five patients (age 55.6 ± 11.6, mean ± SD) voluntarily took part in a balance rehabilitation program consisting of postural exercises executed with the biofeedback system for 10 to 20 minutes, twice a day over a 2-week period. Bipedal postural control was assessed with a force platform before rehabilitation and on the day of discharge in four sensory conditions: (1) eyes open (EO)/Firm support, (2) eyes closed (EC)/Firm support, (3) EO/Foam support, (4) EC)/Foam support. The standard deviation of the centre of foot pressure (CoP SD) in the mediolateral (ML) and anteroposterior (AP) axes (measures of the variability of postural sway) was used to assess postural behaviour. An analysis of variance (ANOVA) was applied to the CoP SD. Post-hoc analyses (Newman-Keuls test) were performed whenever necessary. Level of significance was set at 0.05.

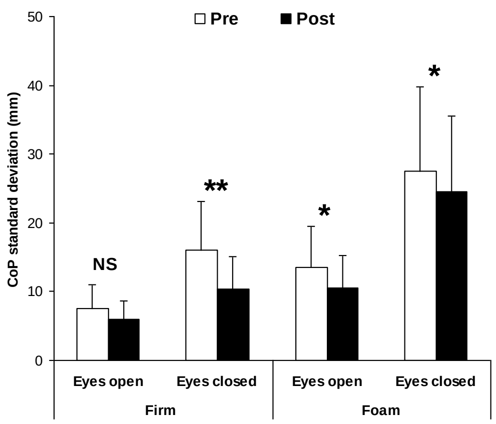

Figure 1. Mean and standard error of standard deviation of the CoP (*p<0.05; **p<0.01, NS: p>0.05).

Results

Analysis of the CoP SD showed significant main effects of Support ($p<0.01$) and Vision ($p<0.01$), a significant interaction Support x Vision ($p<0.01$), and a significant triple interaction Session × Support × Vision ($p<0.05$). As illustrated in Figure 1, post-hoc analyses further showed decreased CoP SD in the Post relative to the Pre-session in the EC-Firm, EO-Foam and EC-Foam conditions, whereas no significant difference was observed in the EO-Firm condition ($p>0.05$).

Conclusions

These preliminary results suggest that a balance rehabilitation program with postural exercise performed with a head position-based tongue-placed biofeedback system could significantly improve bipedal postural control in patients suffering from ataxia due to cerebellar degeneration. Further comparative studies are needed to determine the clinical validity and outcome of balance rehabilitation therapy.

Acknowledgements: This work was supported by the Foundation "Movement without help".

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EFFECT OF 12 WEEKS OF BALANCE EXERCISES ON POSTURAL STABILITY

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Introduction

Adjustment of body posture is a common reason why people like to visit fitness. Incorporating specific functional-balance exercises that challenge the body´s nervous system to improve sensory-motor function could lead to optimal performance and improve body posture.

Methods

Our research was focused on using balance equipment (swissball and Bosu) by visitors of fitnesscenter to improve their body posture in fitness programme. We selected two groups by random, each study sample consisted of 14 probands (8 men, 6 women). Research lasted 12 weeks, three times per week. One of the group used in their fitness programme commonly used fitness equipments. Average age of this group was 36.45± 5.68 years old, average body weight was 81.92± 18.26 kg, average height was 175.53± 8.89 cm and average BMI index was 26.29± 3.95. Second group used special balance equipment, swissball for seating exercise and Bosu for standing exercise. Average age of this group was 34.92 ± 6.04 years old, average body weight was 76.69± 15.93 kg, average height was 177.76± 7.17 cm and average BMI index was 24.2± 4.56. Both groups were supervised by personal trainer to keep correct technique during exercises. Independent blind assessment of body posture was used by three specialists to obtain necessary data. We used method by KLEIN – THOMAS, modified MAYER (1978). They rated images in 7 parameters (round back, forward extended shoulders, protrusion shoulders, kyfosis, lordosis, weakness abdominal muscles, head offset) from side view and 5 parameters (asymmetry characters, shoulder height difference, bow head, scoliosis, sloping basin) from back view. They used 5 levels scale rating. First level was excelent and 5^{th} was very poor. We compared average values of evaluation made by all specialists before and after research of each proband. For comparing values inside groups we used Wilcox T – test. For comparing values between groups we used non-parametric Mann–Whitney U–test.

Results

Comparing values before and after research we came to these results: in the group, which used commonly used fitness equipment, the biggest difference was observed 8.3%, in the assessment of protrusion shoulders. In the group used swissball and Bosu the biggest difference was 19.3% ($p<0.01$), observed in the assessment weakness abdominal muscles. When comparing the differences round back we found 10% ($p<0.05$) difference, comparing forward extended shoulders we found 12.6% ($p<0.05$) difference, comparing protrusion shoulders we found 5.7% ($p<0.05$) differnce, comparing weakness abdimonal muscles we found 11.0 % difference, comparing head offset we found 18.1 % difference. Comparing asymmetry characters we found 6.6% difference ($p<0.01$), comparing shoulder height difference we found 9.5% ($p<0.05$) difference, comparing bow head we found 2.0% ($p<0.05$) difference. All differences were changes for the group using balance equipment. In parameters kyfosis, lordosis, scoliosis and sloping basin we had no changes in both groups, what confirms, together with the known researches [1, 2], that the changes need for action some time as research is under way.

Conclusions

Measured values showed bigger improvement in the monitored parameters in the group with balance equipment. The efficiency of the training programme is outlined by subjective evaluation of the probands in the sense of improved feeling and perceiving of their own body, health and general improvement of quality of life. At the end of the reseach we can say, that the use of balance equipment, swissball and Bosu in cooperation with accurate exercising technique is the right way for improvement body posture.

Acknowledgements: This project was supported by the Scientific Grant Agency of the Ministry of Education of Slovak Republic Academy of Sciences (No.1/0503/11).

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DOORWAY-PROVOKED FREEZING OF GAIT IN PARKINSON'S DISEASE

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Introduction
Freezing of gait in Parkinson's disease (PD) can be difficult to study in the laboratory. Here we exploit the fact that freezing episodes occur in tight spaces or doorways for around half of PD patients who freeze [1]. Recent studies have built on this observation by showing that in laboratory settings 'freezers' (PD patients susceptible to freezing episodes) slow down excessively as they approach a doorway [2, 3]. We investigate the use of a variable-width doorway to provoke freeze behaviour together with new objective methods to measure it. With this approach we compare the effects of anti-parkinsonian treatments (medications and deep-brain stimulation of the subthalamic nucleus) on freezing and other gait impairments.

Methods
Ten 'freezers' (8 males; age: mean 59.8, SD 7.3 year) and 10 control participants (8 males; age: mean 62.8, SD 5.8 year) were studied. Whole-body kinematics were measured (Coda, Charnwood Dynamics) while participants walked at preferred speed in each of four doorway conditions (no door present, door width at 100, 125 and 150 % shoulder width) and in four treatment states (offmeds/offstim, offmeds/onstim, onmeds/offstim, onmeds/onstim). Two objective definitions of 'freeze-like events' (FLEs) were based on the assumption that freezes are rare, episodic events which should be considered relative to each participant's baseline walking performance. One was defined as an unusually high double support time, being more than 3.1 standard deviations above the mean, and the other as a period in which progession velocity dropped below 10% of baseline.

Results
With no doorway, the Parkinson's group showed characteristic gait disturbances including slow speed, short steps and variable step timing. Treatments improved these disturbances. Although explicit perceptual judgements of door width were normal, the Parkinson's group slowed further at doorways by an amount inversely proportional to door width, suggesting a visuomotor dysfunction. This was not improved by either treatment alone. Finally, freeze-like events were successfully provoked near the doorway and their prevalence significantly increased in narrower doorways. These were defined clinically and by the two objective criteria which correlated well with clinical ratings. The risk of freeze-like events was reduced by medication but not by deep-brain stimulation.

Conclusions
Freeze behaviour can be provoked in a replicable experimental setting using the variable-width doorway paradigm, and measured objectively using two definitions introduced here. The differential effects of medication and deep-brain stimulation on the gait disturbances highlight the complexity of Parkinsonian gait disorders and their management.

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CONTEXT-DEPENDENT SENSORY SIGNALS TRIGGER COMPLEX COMPENSATORY REACTION

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Introduction
Free-fall of a subject elicits a response in the soleus muscle at 75 ms of latency triggered by otolith signal [1]. Stretching the soleus muscle by backward translation of dorsal rotation of a supporting platform upon which a subject stands triggers a monosynaptic spindle Ia mediated short-latency response around 40 ms and a group II mediated medium-latency response around 90 ms; the latter is reduced by a stabilized 'postural set' [2, 3, 4]. A tibialis anterior stabilizing response follows at about 130 ms, and is also reduced by stabilization. We have examined the triceps surae motor response following a forward-fall protocol requiring stepping to recover balance, both under control conditions and after a conditioning period leading to response adaptation.

Methods
Subject was maintained inclined forward thanks to a cable connected between the back of subject's abdominal belt and an electro-magnet mounted on a dynamometer. Different anatomical attach was used, abdominal region, thighs, or scapular region. Cable length permitted to vary subject initial inclination. Time of release of the cable was unknown to the subject. In the control situation, the instruction was to walk to recover the balance. In the "release-catch" condition where the fall was arrested a short-time after the release, the instruction was to keep the feet on place. Ground reaction force and surface EMG of soleus and tibialis anterior were recorded.

Results
Balance recovery following a forward-fall includes a motor reaction to the fall then the production of a step to recover balance. The pattern of EMG reaction starts with a bilateral activity in soleus at 65 ms latency. Then, the motor pattern diverges depending on the functional role of the leg (starting or supporting leg). The burst of soleus of starting leg lasts roughly 120-150 ms, and is followed by a tibialis anterior activity associated with foot swing. The burst of the stance soleus lasts longer and ends at around the time of contralateral foot-landing.
Several evidences discard the possibility that the early response in soleus originates from soleus group I afferents, or from vestibular or visual information. Manipulation of the experimental conditions suggested that the soleus early response originated from abdominal sensory receptors and involves a supra-spinal long-loop circuit. Under the condition "release-catch", this response remains stable, whereas the stepping synergy soon disappears, indicating strong modulability of the fall-braking pattern. Abruptly un-restraining the subject after adaptation releases a complete stepping strategy again, indicating sudden withdrawal of adaptation effects under critical conditions. The latency of stepping motor activity in critical case of fall is around 250 ms.

Conclusions
Sensory signals which trigger compensatory reaction are context-dependent and could involve supra-spinal long-loop. Stepping motor program can be inhibited, but can be released very quickly.

Keywords: *balance control, sensori-motor organization, biomechanics*

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AN OPEN CUSTOMIZABLE MODULAR PLATFORM FOR ANALYSIS OF HUMAN MOVEMENT IN THE LABORATORY AND OUTDOORS

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Introduction

New trends in analysis of human movement promote small low-cost portable devices and combine them with the traditional fixed lab-equipment such as force plates and stereophotogrammetry [1]. These new portable devices open for new applications, such as analysis of movement in daily situations and for new biofeedback possibilities as training assistant for rehabilitation or sportive activities [2]. However, currently available systems are often closed and/or designed for a specific application. We developed an open platform able to adapt to a number of different applications by enabling the analyst to select its sensors and customize the processing algorithms.

Methods

After describing a number of use cases, functional and technical requirements were derived and a first prototype device implemented. Such device is able to collect and process data in real-time from any combination of six sensors from the following list: inertial movement units (IMUs), GPS, cameras and pressure sensors. An IMU consists of a 3D accelerometer, a 3D gyroscope and a 3D magnetometer. Further, the device provides basic acoustic, visual and tactile biofeedback. Based on a Linux operating system, the software is a combination of open drivers and C code. Data is stored in a standard text format. In addition, the device is wireless capable.

The device was verified outdoors with a traffic safety application designed for testing purposes. The application used the following sensors: two IMUs, GPS, one camera, one 3D accelerometer and one pressure sensor. Three participants walked a 500-m loop with four zebra crossings. A total of eight test runs were made. At each crossing, the participants were instructed whether to scan for coming traffic by turning the head left and right, or just cross the road without scanning (after the experimenter had made sure no traffic was coming). The application comprised of three algorithms to detect: 1) the presence of a crossing, 2) the initiation of gait, 3) the head scanning movement - to determine whether or not to give a warning feedback. System performances were assessed by calculating sensitivity and specificity for the three algorithms.

Results

Feedback was provided with 87% success rate. Specificity and sensitivity are reported in Table 1 for the three algorithms. Gait initiation was detected in all tests in 0.4±0.2 s. Head scan was detected with 90% success rate. Crossing detection had poor performances which originated from the low GPS accuracy (8.6±4.8m).

Table 1 System Performance

Algorithm	Sensitivity	Specificity
Gait Initiation (GI)	100%	100%
Head Scan (HS) + GI	84.2%	100%
Crossing + HS + GI	84.2%	93.3%

Conclusions

The portable device developed in this study collects and processes in real-time information from a custom number of sensors such as IMUs, GPS, cameras and pressure sensors. Further, this device provides basic visual, audio and tactile feedback and relies on totally open software. The openness and flexibility of such device make it suitable for many applications spanning from biofeedback application in laboratory to activity assistance in a naturalistic set-up.

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NEW DEVELOPMENTS IN EMG-BASED ASSESSMENT OF MOTOR FUNCTION AND ACTIVITY: IMPLICATIONS FOR RESEARCH AND CLINICAL PRACTICE

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Introduction

Objective classification of impaired neuromuscular function and reliably monitoring the outcome through therapeutic interventions are of utmost importance in rehabilitation medicine. The science of electromyography has been evolving rapidly in recent years. Focused research and the advent of new technology have made objective examination of motor performance possible on an electrophysiological basis. In addition to the traditional diagnostic needle EMG technique, acquisition of EMG with surface electrodes has reached a point where monitoring the motor control and performance aspects of patients in a clinical environment or examining ergonomics in the workplace has become both feasible and simple to perform.

Methods and results

This lecture is designed to provide the audience with an overview in the innovative use of recent electromyographical developments in rehabilitation medicine and research. It provides an in depth understanding of the physiology and pathophysiology of the underlying mechanisms of EMG signal recording, and exposes the participants to major applications both in the diagnosis and classification of impaired motor control and motor performance.

Keywords: *SEMG, motor control, movement control*

PASSIVE ARM MOVEMENTS INCREASE RHYTHMIC ACTIVITY IN THE HIP JOINT UNDER VIBRATION

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Introduction

The rhythmic arm movements during human locomor tasks has been viewed as a consequence of coupling between hypothetical pattern generators for the lower and upper extremities [1, 2]. Recently we found that passive arm movements (PAM) rhythmically performed in subject being under vibration increased rhythmic activity in the leg joints up to initiation of unvoluntary step-like movements. To explore the effect of such afferent stimulation on the rhythmic activity in legs, we performed the experiment with different parameters of PAM.

Methods

In 9 (4 males, 5 females) healthy volunteers, 28.9±11.8 yrs (mean±SD), the kinematics of the arm and leg joints were recorded during the HipRelease test - in subjects lying on the left side with right arm and leg suspended, the right leg was extended by experimenter up to 20° backward to the craniacaudal line of body and passively released. The decreasing oscillations in hip and knee joints were recorded with goniometric system ('MBN-biomechanic', MBN, Russia), the rhythmic activity in hip joint was estimated by the decrement of oscillation (HipDecr = ln A1/A2; A1, A2 - amplitude of the first and the second oscillations). PAM were performed by experimenter as rhythmic flexion-extension in shoulder, elbow and both joints with 2 amplitudes of arm motion (100°, 50°) at 2 frequencies (comfortable and high), with 7 trials of 20sec for each condition. The sequence of the conditions was randomly balanced. Additionaly, the movements in shoulder and elbow joints (50°, comfortable speed) were performed within 3 segments (upper, middle, lower) of angular displacement. Vibration of the Achilles tendon (60Hz, 1mm amplitude) was constantly applied during the experiment.

Results

In both, individual and group data HipDecr was smaller with PAM as compare to the same test without them (p=0.001) (Fig.1A).

Effect of PAM performed in shoulder and elbow joints statistically differed in 5 subjects with no common trend. The comparison between the single-joints and bi-articular movements showed more influence of bi-articular PAM (Fig.1B), the differences were statisticaly significant (p=0.033). PAM with high and low amplitude as well as PAM performed at different frequencies showed no significant differences. There were no differences in effect of PAM performed within different ranges of velocity (high, middle and low-calculated on the base of amplitude and frequency data). Effect of PAM performed within different segments of the angular displacement also showed no significant difference.

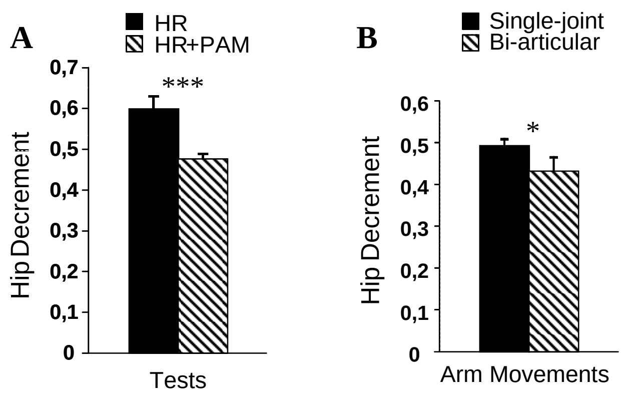

Figure 1. Rhythmic activity in hip joint measured as a decrement of decreasing oscillations (HipDecr) at:
A) HipRelease tests performed with and without PAM;
B) HipRelease tests performed with rhythmic single-joint and with bi-articular arm movements (means across subjects with SE bars).

Conclusions

The afferent stimulation from passively moving arm increases the rhythmic activity in the hip joint with more effect of bi-articular movements as compare to single-joint movements but regardless to the other specific parameters of movements. The data supports hypothesis of interaction between central pattern generators for homonimous arm and leg.

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LATERAL BALANCE CONTROL DURING WALKING: CAN THE EXTRAPOLATED CENTRE OF MASS MODEL PREDICT FOOT PLACEMENT DURING LATERAL EXTERNAL PERTURBATIONS?

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Introduction
Balance control in bipedal walking poses challenges in the unstable lateral direction. The feet have to be placed a certain distance outside the Centre of Mass (CoM) to timely redirect the movement contralaterally, and prevent falling over the stance leg. The previously developed Extrapolated Centre of Mass (XcoM) model [1] extends the classical inverted pendulum with a velocity component of the CoM to determine foot placement and stability margins. It is hypothesised that a wide stride is more stable than a small one. The model is tested for unperturbed normal walking, but it is unknown how it compares to real-life foot adjustments in response to external perturbations. This study investigates the validity of the model when lateral perturbations are applied during two phases of the gait cycle.

Methods
Ten healthy subjects (5 men, 5 women, age 24.1 ± 2.2, mean ± SD) walked on a treadmill and were pushed laterally during the double stance phase and the swing phase, in random steps using a linear motor. CoM movements and foot placement were recorded using a VICON system. We compared the measured foot placement with the one calculated by the model. The model calculated foot placement of the upcoming step was based on the measured CoM position, velocity and the present foot position at the moment of toe-off.

Results
In response to lateral perturbations during the double support phase oppositie to the CoM movement, the XcoM model predicted a decreased step width in the upcoming step, as the situation is more stable. This was followed by an increased step width in the next step, creating more stability. Compared to the model calculations, the pattern in the measured foot placement showed qualitatively the same pattern, although humans react one step later. Furthermore, the XcoM model was not accurate in predicting the exact foot placement. For the perturbations during the swing phase a different pattern was observed. Humans were able to adapt their foot placement during the swing phase. However, the model was not effectively dealing with this adaptation.

Conclusions
The model gives qualitatively good predictions. However, to obtain quantitative good predictions the model should be adapted. Model calculations are very sensitive for the estimation of step time. This estimation is difficult as only swing time is included and step time should be lengthened with the double support phase. Furthermore, other human compensation methods for instability, like trunk movements, were not included in the inverted pendulum model; therefore humans are able to walk with smaller step widths than calculated by the model. The model currently falls short in predicting foot placement when the perturbation occurs during the swing phase as it determines foot placement at the start of swing (toe-off). We are now extending the model to continuously monitor the CoM movement to make online corrections.

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BALANCING WITH AN UNSTABLE OBJECT: THE ADAPTATION TO A NOVEL DYNAMIC TASK

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Introduction

In this work an unstable object, namely a plastic tube partially filled with water was adopted as a source of instability. Theories of motor learning suggested that the process of acquisition of new motor skill proceeds through several stages of progress followed by learning plateau [1]. It is postulated that repetition of the balance exercises with the water filled tube presents an opportunity to examine subject's adaptation process to a particularly difficult task.

Methods

Sixteen (8 females, 8 males) healthy subjects (age: 23.5 ±3.5 years, weight: 72 ±12.7 kg, height: 1.74 ±0.1 m) participated in the study. Participants were free from any known motor, vestibular, or neuromuscular impairments. The experimental methodology was approved by the Research Ethics Board at the University of Windsor. Trials were performed with the use of Attitube®, a plastic tube of weight and length (10 kg, 1.57 m) partially filled with water. Sloshing movement of water inside the tube was the source of instability. Subjects were tested under two different posture conditions standing barefoot for 60 seconds on a force plate. The first posture involved a quiet standing (QS), repeated twice. The second posture was a standing with a tube (T), repeated ten times. Participants were instructed to hold the tube as steady as possible with their elbows flexed at 90 degrees. A rest time of 1-2 minutes was provided between individual trials. Center of foot pressure (COP) data were collected using the force plate (AMTI OR6-7, USA) at a sampling rate of 50 Hz. COP data were processed offline in MATLAB™ R2007b.

Results

Path, range and velocity of COP were calculated for both anterior-posterior (AP) and medio-lateral (ML) plane. An example of COP path in ML plane is shown in Fig. 1. There was a marked decrease of postural balance by a factor of four from quiet standing to position with tube. There is a clear decrease in the COP path values for consecutive ten positions with the tube from 753 mm in T1 trial to 571 mm in T10 trial. Similar trends were observed in COP for range and velocity. In the other plane (AP) these trends are not as much pronounced. The decreasing COPs with each trail are indicative of the subject adaptation to a required task of balancing of the unstable object.

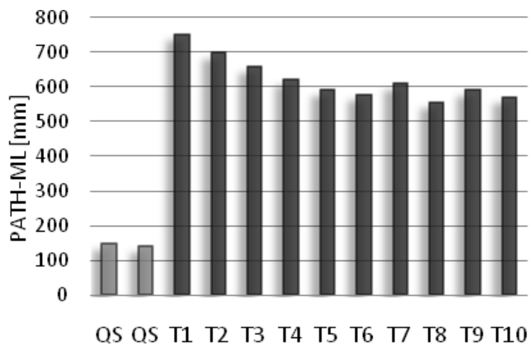

Figure 1. Average path of COP in medio-lateral (ML) plane across consecutive trials, QS-quiet standing, T-standing with the tube.

Conclusions

It is shown that the task of balancing with an unstable object presents an increased level of postural imbalance. However by the repetition of this particular task the subjects seem to learn how to cope with handling of the tube and adapted to worsened balance conditions. This research suggests that the partially filled tube with water could be a useful tool in studies of balance control and rehabilitation.

Keywords: *unstable object, balance control, motor learning, coordination*

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POSTURAL STRATEGY OF THE MARKSMAN

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Introduction
Initially, the brain is unable to program a successful motor act. It was obvious for Bernstein and he made his listeners share this, offering them a short experience inspired by gun firing. Only training, that reduces the mistakes between the desired act and the achieved one, can compensate for this brain inability. For Bernstein, this training started by decreasing the number of the degrees of freedom of the motor act, even if its final aim was a free and harmonious play of all the degrees of freedom. In fact gun shooters at the highest level block the degrees of freedom of their ankle joints and manage to block their left-right postural sway too, but not their antero-posterior sway.
Methods
About one hundred gunmen of various performance levels from the "Fédération Française de Tir" have been recorded on the occasion of several experiments. Recordings have been made on stabilometric clogs [In Tech, Marseille], in standard position of the feet or in firing position, with or without real fire, with or without simultaneous recording of the line of sight by Scatt system. Analyses of the stabilometric signal used the classic parameters of the Center of Pressure as well as the parameters of the Center of Gravity. Statistical analyses have been guided by principal component analyses.
Results
It has been found:
- a statistically significant effect of the training on the decrease of the speed of the left-right postural sway of gunmen,
- an effect of training on the postural strategy of gunmen that connotes a decrease of the degrees of freedom of the ankle joints.

Conclusions
A new domain is then to be explored between these observations and the conclusions that trainers can draw from them.

FREQUENCY-DOMAIN IDENTIFICATION OF HUMAN BALANCE CONTROL

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Introduction

One topic of debate is whether physiological control mechanisms, such as standing balance, can be modelled as technological control systems and, if so, what control algorithm is used. Competing approaches include the (non-predictive) proportional-integral-derivative control algorithm with added time delay which has been successfully used to fit data from human control experiments [1], predictive feedback control, such as the continuous-time state-observer-predictor-feedback control structure of Kleinman [2] which has been shown to be applicable under a range of experimental conditions, and intermittent control which was first developed in the context of refractoriness [3] but has recently received attention in relation to human balance control [4]. There are thus three competing hypotheses: non-predictive control, predictive control and intermittent control. Extending our previous work on non-predictive and predictive control [5], in this work we use frequency domain system identification techniques applied to experimental, perturbed human-in-the-loop data to provide an objective test of these three alternative control-theoretical models of the human control system.

Methods

Experiments were conducted in which 11 volunteers were instructed to control a second order unstable system approximating the dynamics of a standing human, represented by a dot on the screen (the system output) using a joystick (representing the system input) [6], while the system was excited using a periodic multisine disturbance signal [7]. A two-stage approach to the identification is used: first, the closed-loop frequency response function (FRF) is derived using the periodic property of the experimental data, followed by the fitting of a parametric model. While this approach is well-established for non-predictive and predictive control, it is here used for the first time with intermittent control, based on recently derived frequency domain properties [8]. For each controller structure, the estimated time-delay and the best fit value (the minimal mean-squared difference between the estimated FRF and its parametric fit) were calculated.

Results

Similar best fit values were obtained for the predictive and intermittent controllers (5.2±2.5 [10^{-3}] and 5.3±2.5 [10^{-3}], mean±SD), whereas the non-predictive controller resulted in larger values (6.6±4.1 [10^{-3}]). Intermittent and predictive controllers gave similar time delay values (192±45ms and 193±42ms, respectively) which were in agreement with non-parametric estimates [6] and significantly larger than those obtained with the non-predictive controller (97±37ms).

Conclusions

A two stage process has been used to identify controllers from closed loop experimental data of human control. Only the predictive and intermittent controllers resulted in time-delays which were in agreement with physiological measurements [5, 6], suggesting that a predictive component is inherent to human control. The observation that predictive and intermittent control approximate the data equally well implies that sustained human control is compatible with intermittent control, and that previous results suggesting a continuous control model for the human control system do not rule out intermittent control as an alternative hypothesis.

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POSTURAL CONTROL IN NORMAL RHESUS MONKEYS DURING QUADRAPEDAL STANCE

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Introduction

Loss of vestibular sensation causes difficulty maintaining postural control and gait as well as stable vision. There is a groving interest in development of vestibular prosthesis, a novel approache to restore vestibular hypofunction. The overall goal of this study is to characterize postural control in normal rhesus monkeys, to define the contributions of vestibular cues to postural control, and to determine if a vestibular prosthesis can improve postural control after vestibular ablation.

Methods

We have studied postural control in normal rhesus monkeys during quadrapedal stance using two paradigm: 1) we measured sway during quiet stance with the support surface configured in 4 ways – wide stance with thin (gum) rubber covering the footplates, wide stance with foam covering the footplates (which distorts somatosensory inputs), and narrow stance with gum or foam rubber on the footplates; 2) we measured postural responses induced by roll tilt of the platform. Platform motion is derived from a pseudorandom ternary sequence (PRTS), which has the characteristics of white noise and covers a frequency spectrum from 0.05 to 2.5 Hz and the peak amplitude ranged from 0.5 to 8.0 degrees.

Results

We found that sway of the trunk increased as the test condition was made more difficult, e.g. with the footplates covered with foam and in the narrow configuration. Body-sway responses to PRTS stimuly were analyzed using Fourier methods to calculate gain and phase as a function of stimulus frequency. We found that at mid-frequencies trunk tilt increased linearly with platform tilt for smaller tilt amplitudes but then saturated for higher amplitudes.

Conclusions

These results suggest that the animals primarily used somatosensory information to control balance at lower amplitudes (e.g. oriented the body with the platform) but switch towards vestibular/gravitational inputs at higher amplitudes (e.g. oriented the body towards the earth-vertical gravitational vector). We now will repeat these same paradigms after bilateral vestibular ablation is produced with aminoglycosides, and then will study posture while the ablated monkeys receive head motion information from an implanted vestibular prosthesis.

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EFFECT OF COP-BASED VISUAL BIOFEEDBACK ON BALANCE CONTROL IN ELDERLY

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Introduction
Many aspects of postural control decline with age [1]. Sensory biofeedback offers the possibility how to improve the postural stability in older people. Visual biofeedback (VBF) is a control mechanism of postural activity using supplementary visual input. Many studies reported improvements in postural stability after visual biofeedback-based training of balance in elderly [2]. However, the extent to which biofeedback information can improve balance has not been determined yet.
Methods
20 young subjects (6 men, 14 women; mean age 23,5 years) and 13 elderly (6 men, 7 women; mean age 72,9 years) participated in the study. The balance control was measured during quiet stance in 4 conditions: stance on a firm / foam surface with eyes open / with VBF. During conditions with VBF subjects were informed about their body tilts as a moving red point on the screen controlled by centre of foot pressure (CoP) signal from a force platform. The body sway was quantified by CoP displacements and by trunk tilts measured by two ADXL203 dual-axis accelerometers positioned at the upper (Th4) and lower (L5) trunk. Three parameters were evaluated: Ay (amplitude in anterior-posterior direction), Ax (amplitude in medial-lateral direction) and RMS (root mean square).
Results
The results from 2-way repeated measures ANOVA showed that the postural improvement due to VBF was the most evident by decrease of CoP displacements. We found statistically significant influence of VBF on all evaluated parameters RMS, Ay and Ax. Data from the accelerometer placed at L5 showed the statistically significant influence of VBF on parameters RMS and Ay. Data from the accelerometer placed at Th4 showed no statistically significant effect of VBF on reducing body sway. We observed a significant effect of age on postural sway during the situations with VBF. Decrease of values RMS, Ax and Ay was lower in older subjects than young subjects. Significant interaction was also found between the factors: VBF - surface. VBF led to a larger reduction of RMS when subjects were standing on the foam surface than on the firm surface. Subsequently Student's *t*-test showed that older people were able to improve their balance due the VBF only during the stance on foam surface.
Conclusions
According to these results we can conclude that the CoP-based VBF has the most stabilizing effect on CoP postural sway, less on lower trunk body tilts and disturbing effect on upper trunk body tilts. It seems VBF is the most effective in reducing postural sway mainly on the segment from which it is sensing. We also found out that older people are not able to utilize VBF as effectively as young adults. We suggest that elderly may need greater magnification of additional visual information of CoP positions on the monitor. Especially elderly people were relied upon to a greater extent on VBF when standing on a foam surface. Condition with foam support surface likely activates the brain function with sensory interaction and therefore it has a stabilizing effect on postural stability during the condition with VBF. This improvement may suggest a stronger reliance on vision to maintain balance in the foam condition. More details are still needed to understand which aspect of additional information in which situation is the most useful and relevant for improving balance in elderly population to adjust the biofeedback devices for their balance rehabilitation.

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DOUBLE INVERTED PENDULUM MODEL OF REACTIVE HUMAN STANCE CONTROL

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Introduction

When maintaining equilibrium in upright stance, humans use sensory feedback control for coping with unforeseen external disturbances, this despite biological 'complications' such as noisy and inaccurate sensor signals and considerable time delays. System identification in humans has led to a control model that we currently test under various conditions (DEC model, **d**isturbance **e**stimation and **c**ompensation [1]). Using on-line multi-sensory interactions, the model extracts estimates of four external disturbances from the manifoldness of disturbance situations: (1) field forces such as gravity, (2) contact forces such as a push having impact on the body, (3) support surface tilt and (4) support surface translational acceleration. The sensors used are (in absence of vision): vestibular, joint angle and joint torque. Disturbance compensation is performed by feeding the estimates rather than the sensory signals into a local proprioceptive feedback loop ('disturbance rejection'). Model testings include hardware-in-the-loop simulations using a robot. Here, we explore into an extension of the model such that it controls double instead of single inverted pendulum biomechanics. This implies adding a trunk segment (on hip joint) to the leg segment (on the ankle joint), which may entail a change in body configuration (and shift of COM in its intra-body location) as well as inter-segmental torques.

Methods

In the corresponding human experiments, we presented healthy subjects (eyes closed) with pseudorandom tilts of the support surface (frequency, 0.016-2.2 Hz). We allowed for, but not encouraged explicitly, hip motion. Trunk and leg angular motion was measured opto-electronically and center of mass (COM) motion was calculated thereof. In addition, we recorded center of pressure (COP) shifts. The data was preliminarily analyzed in terms of Bode histograms. In the model (Matlab/Simulink), the ankle joint control was made to control COM-space angle and COM gravitational torque (calculated from the combination of trunk and leg segment motions [2]). For the hip joint we used simply the single inverted pendulum DEC control with its inbuilt compensations for support base motion (i.e. of leg segment). For the robot experiments, we implemented the model into PostuRob II (which is provided with hip and ankle joints, see www.posturob.uniklinik-freiburg.de) and used it for additional simulation.

Results

Human: The human tilt responses showed a typical gain and phase curves pattern, this despite considerable inter-subject data variability and across different tasks (finger pointing in body coordinates, 1, and space coordinates, 2, versus no task, 3). During the low frequency tilts, trunk and COM (≈ leg segment) excursions were approximately in phase with the tilt, the trunk being held slightly better upright than the legs. With increasing frequency, the leg segment, and even more so the trunk showed an increasing phase lag. Then, trunk excursion gain increased, becoming larger than that of the leg segment ('gain cross-over'). Model simulation: The model in its extended form (ankle and hip joint controls) kept COM well above the base of support. The patterns of COM, leg, trunk and COP gain and phase curves over frequency resembled those of the human subjects. Exploring into the dynamic inter-segmental torques, we found that (a) their effect on the ankle joint is reduced to a large amount by our controlling of the whole body COM, and (b) their effect on the hip joint is very small and covered, as expected, by the DEC mechanism. Robot experiments: PostuRob II was freely standing on the motion platform in our posture lab. It successfully balanced the tilt stimuli, showing in the Bode plots very similar response patterns as the human subjects.

Conclusions

The DEC control concept is a very simple and computationally parsimonious method for controlling reactive balancing on the basis of multisensory feedback. We present evidence that it is capable of controlling a multi-segment body despite inter-segmental torques and biological constraints such as inaccuracies, noise and time delays. In further simulations (SimMechanics), we extended the DEC to control even four joints biomechanics.

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THE EYES HAVE IT! A PUTATIVE MECHANISM FOR FACILITATORY EFFECTS OF VISUAL CUEING ON TURNING IN STROKE SURVIVORS

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Introduction

Studies of young healthy adults suggest that coordination of axial body segments during steering represents a robust pre-programmed postural synergy triggered by gaze realignment in the desired direction of travel [1]. Since around two thirds of stroke patients show eye movement abnormalities [2] this raises the possibility of a link between eye movement problems and turning deficits. Indeed, our findings suggest that impaired self initiation of turns is a particular problem for a subgroup of participants whose lesions involved the Basal Ganglia (BG); a neural network responsible for controlling the initiation of eye movements and automatic movement sequences such as turning and that initiation of turning can be improved with the use of visual cues [3]. These findings imply that impairments in turning ability, may not be the sole result of physical inability to make appropriate movement patterns but may be caused by impaired ability to generate eye movements to align with the new travel direction. The present study explores the potential mechanism by which external cues may improve turning ability by contrasting turning kinematics in response two types of visual cue: 1) a directional cue that promotes reflexively generated eye movements in the new travel direction and 2) a non-directional cue that does not facilitate gaze shifts but still directs attention to towards the required act of turning.

Methods

Participants (7 male, 7 female, mean age 61 years, range 38 – 79 years), who had suffered a stroke (> 6 months prior to participating) and were able to walk 10m without aid were visually cued to change walking direction by 90°, either left or right, at the midpoint of a 6m path. Conditions (5 trials each) were: 1) directional cues in which the signals to turn were in line with the target travel path and 4) non-directional cues in which the signals to turn were in line with the straight path. Full body and eye kinematics were measured using a Vicon MX motion analysis system and a Bluegain EOG system respectively.

Results

There was a significant interaction effect ($F_{(1,3)} = 5.6$, $p<0.05$) between turn direction (towards either paretic or non-paretic leg) and cue type (directional versus non-directional). Post-hoc analysis revealed that the latency of reorientation onset was significantly delayed when using the non-directional cue but only when turning towards the paretic side (Fig. 1). Eye movement analysis is in progress.

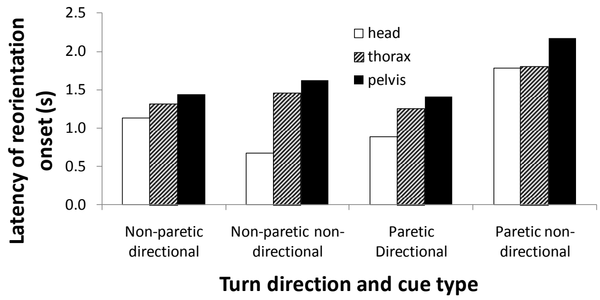

Figure 1. Effects of turn direction and cue type on latency of segment reorientation onset.

Conclusions

These findings suggest that visual cues that promote eye movements in the new direction of travel may be more effective than non-directional visual cues in facilitating turning and provide support for a mechanistic link between oculomotor and turning deficits in neurological patients.

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SOLEUS ACTIVATION DETERMINES STEP LENGTH

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Introduction

Bipedal locomotion requires the generation of propulsive force as well as anti-gravity force to control the fall of the centre of mass during the single support stance. Even if the source of propulsive forces remains under debate, it is clear in the literature that ankle plantarflexor muscles are responsible for the generation of upright force [1, 2]. In addition, the soleus (SOL) muscle restrains forward tibial rotation and stabilises the knee joint [3]. SOL can therefore modulate step length by controlling the duration of double support by favouring or delaying the foot contact of the swing leg.

Methods

In order to determine whether the SOL of the stance leg controls step length, 8 subjects (5 men and 3 women age 23.75±1.39 yrs, height 1.73±0.08 m, weight 67.69±9.38 kg) underwent a forward fall protocol [4]. The subjects were restrained by a cable attached at the abdominal level and fixed to the wall. Their body was inclined at an angle of approx 15 deg. Upon release, subjects made a step to recover from falling. The step length was approx constant across the individual trials. Thereafter, subjects were instructed to continue walking. The first step was used as control, and compared to steps of smaller length, deliberately executed. The EMG of the soleus muscle of the stance leg was measured for the first step and synchronized with the ground reaction force measured via a large force platform (AMTI 0.9x1.8m). If the EMG activity of SOL proportionally changes between the two conditions (normal steps and small steps) then SOL plays a role in determining step length.

Results and conclusions

Performing short steps decreased significantly the duration of the single support phase FO-FC (FO – foot off, FC – foot contact, Fig. 1). In this particular example, this decrease was coupled with an almost complete inhibition of SOL activity during the single support phase in the stance leg. This allowed the CoM to fall freely, thereby producing a smaller-length step. The result indicates that SOL activity controls the duration of the single support phase by damping the fall of the centre of mass. This would necessarily play a role in determining step length.

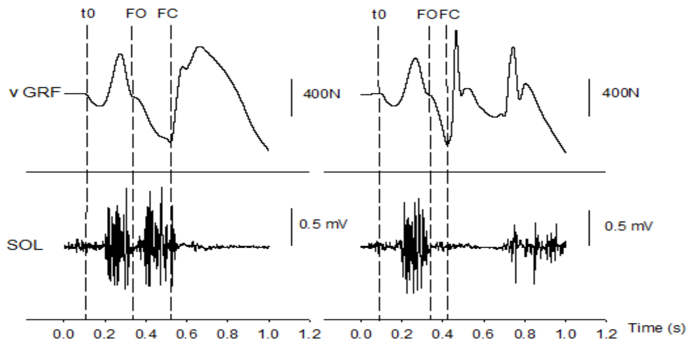

Figure 1. Traces of the vertical ground reaction force (vGRF) and SOL EMG activity for the two forward-fall conditions (left: normal step; right: small step).

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ISAW: INSTRUMENTED STAND AND WALK TEST

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Introduction
Clinical practice to assess mobility relies on subjective scales. The goal of our study was to develop an objective, yet short and easy to use, clinical testing system to measure relatively independent aspects of mobility including postural sway, anticipatory postural adjustments (APAs), gait and turning. ISAW is an attempt to combine several separate tests we developed for wireless, body-worn, inertial into one, quick protocol: the Timed Up and Go (ITUG) [1], Step Initiation (ISTEP) [2] and Postural Sway (ISWAY) [3] tests. We hypothesized that relatively independent aspects of mobility could be measured quickly within a single, clinical procedure.
Methods
ISAW was performed in a hospital hallway. After 30 sec of recording quiet stance, subjects were instructed to walk 7 meters, make a 180° turn and return back to where they started. Ninty subjects with moderate Parkinson's disease (PD) and 30 control subjects were tested. The average age was 65.7 ± 6.6 years. All PD subjects were measured during their ON state and their average UPDRS motor score was 32.5 ± 9.8. Each subject performed 3 trials of ITUG, ISWAY, ISTEP and ISAW. Automatic analysis algorithms calculated 52 ITUG, 7 ISTEP and 38 ISWAY parameters using Mobility Lab software (APDM.com). The same measures were extracted from ISAW. The data was uploaded to a database. To assess absolute agreement between the results of either ITUG, ISTEP or ISWAY with ISAW, Intra-Class Correlation (ICC type A-1) was used. We used factor analaysis and examined the covariance structure of the measures to find out how they are related.
Results
Cross-correlation matrix of ISAW metrics showed lack of correlation among metrics related to 1) postural sway, 2) APAs and 3) gait with significant correlations between metrics within sway, APAs and gait. Factor analysis showed 5 relatively independent factors with metrics grouped approximately by postural sway, gait speed, gait temporal measures, turnk/upper limb motion during gait and gait asymmetry. Gait and turning measures had excellent agreement between ITUG and ISAW: the ICCs for Cadence, Stride-Velocity and Turning Duration were 0.91, 0.91 and 0.85 respectively. The postural sway measures showed good, but lower, agreement between ISWAY and ISAW: the ICCs for the Sway Area, Amplitude and Frequency were 0.63, 0.68 and 0.74 respectively. ISAW trials took on average less than a minutes (59.0 ± 5.1 sec).
Discussion
ISAW is an objective, short and automated method to assess postural sway in quiet stance, APAs for step initiation, dynamic stability during gait and quality of turning in a clinical environment. It measures several different aspects of postural control in a single protocol. We are working on developing the best combined Mobility Score from the ISAW that may predict future falls. Objective, automatic assessment of static and dynamic balance with wireless, synchronized, inertial sensors is ideal for clinical research and clinical practice.

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MOBILITY LAB: AN INSTRUMENTED BALANCE AND GAIT SYSTEM FOR CLINICIANS

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Introduction

Clinicians need objective measures of balance and gait that are practical for use in clinical settings. The goal of our project was to develop a system to instrument balance and gait measurements for clinical trials. A group of scientists interested in solving this problem, for clinicians working with Parkinson's disease, met in Portland, Oregon in a meeting sponsored by the Kinetics Foundation. We decided to use wearable, synchronized sensors to automatically characterize the Timed Up and Go test (ITUG) and sway in quiet stance (ISway). Since then, we have added three more instrumented tests: Step Initiation (IStep), Long Walk (IWalk) and Stand and Walk (ISAW). When we began this project, commercial wearable sensors were wired together for synchronization. However, since then, a start-up company in Portland (APDM) developed small, wireless, synchronized sensors called Opals – ideal for this application. Here we summarize development of the Mobility Lab system, which was launched by APDM in February, 2011.

Methods

Three to six Opals are applied to the body with Velcro straps (two on the shanks and one on lumbar back for gait and sway; an additional one on sternum for sit-to-stand and stand-to-sit transitions; and two on the wrists for arm swing). The Opals are synchronized with an access point and signals from 3 accelerometers, 3 gyroscopes and 3 magnetometers are transmitted to a laptop with radio frequency. A user-interface allows consistent, but flexible testing protocols with conditions and durations set by the user. Except for new turning algorithms, many of the 52 metrics automatically characterizing postural transitions and gait come from published and validated algorithms [1]. The 42 metrics automatically characterizing postural sway in stance have been adapted from CoP algorithms, except for Jerk, the normalized, filtered, integrated accelerometer signal [2]. The initial synchronization and attachment of the sensors on the body takes less than 5 minutes. This system has already been tested with over 150 patients with Parkinson's disease, 50 with Multiple Sclerosis and on over 80 control subjects by research assistants, physical therapists and neurologists at OHSU.

Results

- Sensitive to Early Disease: ROC areas above 0.7 for PD [3]
- High Test-Retest Reliability: with ICC of 0.93 for a combined score
- Clinical Validity: Metrics are correlated with UPDRS (r=.58 - .73) and combined score r=.78
- Track Disease Progression: Turning duration, arm swing and sway jerk progress in untreated PD
- Responsive to Drug and Exercise: some metrics sensitive to levodopa and exercise
- Predicts Falls: Sway in stance predicts future falls in PD

Discussion

Mobility Lab provides clinical researchers and clinicians a fast, portable, reliable, instrumented system for quantifying balance and gait in the clinic. It is unique in allowing customizable protocols, instant results compared to normal values with easy-to-use video instructions for clinicians and patients.

Conflict of interest: Drs. Horak, Salarian, McNames and Holmstrom have significant financial interests in APDM, a company that has a commercial interest in the results of this research and technology. This potential conflict of interest has been reviewed and managed by OHSU, PSU and the Integrity Oversight Council.

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OPTIMAL WALKING SPEED FOLLOWING CHANGES IN LIMB GEOMETRY

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Introduction
What is the role of body proportions in gait optimization? The principle of dynamic similarity [1] states that the optimal walking speeds of geometrically similar animals are independent of size when speed is normalized to the dimensionless Froude number (Fr). Furthermore, various studies have shown similar dimensionless optimal speed (Fr ~0.25) for animals with quite different limb geometries. Here, we wondered whether the optimal walking speed of humans depends solely on total limb length or whether limb segment proportions play an essential role.
Methods
While the characteristic body length for computing the Froude number is most commonly considered as the leg length, the importance of a particular limb segment configuration has not been investigated. If optimal walking speed solely depends on the limb length then, when subjects walk on stilts, they should consume less metabolic energy at a faster optimal speed than when they walk without stilts. To test this prediction, we compared kinematics, electromyographic activity of leg muscles and oxygen consumption in adults walking on a treadmill at different speeds with and without articulated stilts that artificially elongated the shank segment by 40 cm.
Results
Walking on stilts involved a non-linear reorganization of kinematic and electromyography patterns. In particular, we found a significant increase in the alternating activity of proximal flexors-extensors during the swing phase, relatively smaller oscillations of the distal segments and significantly shorter normalized stride lengths. The minimal metabolic cost per unit distance walked with stilts occurred at roughly the same absolute speed, corresponding to a lower Fr number (Fr ~0.17) than in normal walking (Fr ~0.25). Finally, even though stilt walking experience may improve performance [4], the 'natural' dimensionless walking speed on stilts was found to be slower than that predicted from the proportional increment in the limb length [2, 4, 5].
Conclusions
The present study does not suggest a violation of the dynamic similarity theory. Rather, we highlight that animal anatomy and individualized limb segment distortions are optimized in such a way that it (Froude number) can explain optimal walking velocity. Our findings demonstrate that specific limb segment proportions may play an essential role in the kinematics and energetics of walking as well as body proportions are inherently incorporated in our locomotor body scheme [3]. This kinematic adaptation and altered metabolic profile support the popular creed on optimal body proportions and may provide further insight into the adaptation of bipedal gait.

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THE ROLE OF FOOT ARCHITECTURE IN POSTURAL CONTROL

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Introduction
Anthropological and podiatric research suggests that the human foot evolved a unique design for propulsion and support. In theory the arch and toes must play an important role in postural control, however, many postural studies tend to focus on the simple hinge action of the ankle joint and other suprapedal sensorimotor control. To further investigate the role of foot anatomy and sensorimotor control of posture, we quantified the deformation of the foot arch, as well as we studied the effects of local perturbations applied to the toes (TOES) or 1st/2nd metatarsals (MT) while standing.
Methods
Kinematic, center of pressure, and electromyography measurements of the lower extremities during quiet stance and perturbed posture were collected on 12 subjects (8 women and 4 men) between the ages of 26-44 (33±5 yrs) years, with an average height of 171.6±7.9 cm and average weight of 75.0±15.5 kg. In the first protocol, we quantified the deformation of the foot arch under stationary loading (n=7) with subjects seated, feet placed on a force plate (AMTI force plate, Watertown, MA), and knees flexed at a 90° angle. A displacement probe (Series 200 from Trans-Tek, Inc., Ellington, CT) was placed on the dorsum of the foot approximately over the cuneiform bones but avoiding the dorsiflexor tendons (e.g. extensor hallicus longus), which measured the change in the height of the foot arch when we placed and lifted a 10 kg weight on the knee. In a second protocol, using the displacement probe on the foot dorsum, an angular potentiometer (CP-2UK-R250, Midori America Corp., Fullerton, CA) attached to anterior tibia to detect shin anterior-posterior sway, and a force plate to measure center of pressure, data were collected during quiet stance with eyes closed for 60s (n=7) to establish the relation between body sway and foot arch deformation. The third protocol was designed to differentiate functional roles of the foot anatomy by comparing how perturbations to the toes versus the heads of 1st and 2nd metatarsal affected postural control while standing eyes closed (n=12). The subjects' hind-foot was on a stable, fixed force plate, while the forefoot was on a moveable surface (Neurocom, Clackmas, OR). In the TOES condition, the head of the MT I/II as well as the hind- and mid-foot was on the fixed platform while the first three phalanges were on the moveable platform. In the MT condition, the phalanges and 1st and 2nd MT heads were both on the moveable platform while the hind-foot remained on the fixed platform. Perturbations entailed a 2.5 – 6 mm upward displacement (2.5 mm/s) of the anterior moveable platform.
Results
In Protocol 1, loading and lifting the 10 kg weight on the knee respectively lowered and raised the foot arch between 1 - 1.5 mm while the subject was in the sitting position. Less than 50% of this change could be accounted for by plantar surface skin compression. In Protocol 2, during quiet standing, the foot arch probe and shin sway revealed a significant correlation, which shows that as the tibia tilts forward the foot arch flattens and vice versa. In Protocol 3, a 2 – 6 mm upward shift of the MT or TOES revealed significant changes in the EMG of the tibialis anterior and gastrocnemius and the RMS (root mean square) variability of shin sway increased significantly with postural responses being greater in MT condition. The slow return of RMS to baseline level (>30s) suggested that a very small perturbation to either the phalanges or metatarsals changes the surface reference frame which then takes time to reestablish.
Conclusions
These findings show that rather than serving as rigid base of support, the foot is compliant, in an active state, and sensitive to minute perturbations even if the entire hind- and mid-foot is stably supported and the ankle joint is unperturbed. In conclusion, the architecture and physiology of the foot appear to contribute to the task of bipedal postural control with great sensitivity.

Keywords: *foot deformation, proprioception, human posture control*

THE COMPARISON BETWEEN THE HUMAN MOVEMENT IN GAIT AND IN RIDING DURING HIPPOTHERAPY

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Introduction
Hippotherapy can be defined as a method of treatment for patients with movement dysfunctions and/or neurological disorders used by physical and occupational therapists trained in using horses as treatment tools [1]. The rhythmically oscillating back of a walking horse mainly stimulates a rider's postural reflex mechanisms, resulting in the training of balance and coordination [2]. The aim of this study was to compare the movement of selected human body segments in gait and in riding during a hippotherapy lesson.
Methods
Six healthy children (5 girls, 1 boy, mean age 11.5 years, mean body weight 39.2 kg, mean body height 153.5 cm) without any previous horse riding experience volunteered to participate in the study. The hippotherapy was conducted on a 3 horses (thoroughbred, Czech warmblood, Silesian norik). They were prepared in a long and systematic manner for handling unusual situations and tolerating strangers and unusual objects. Contrasting marks were placed on the selected anatomical points on the human body for the assessment of the movement of segments. The recording of movement was taken at the area commonly used in hippotherapy. A physiotherapist routinely corrected the sitting posture of the riders. The gait was analysed at the laboratory for human movement analysis. 3D videography was used for collecting data (4 cameras - Sony HDV 1080i, Sony DCR-TRV 900E, JVC GR-DVL9800, 50 Hz). The basic spatiotemporal and angle parameters were determined by APAS software (Ariel Dynamics Inc. Trabuco Canyon, CA, USA).
Results
The basic values of the range of movement of the pelvis and shoulder in transversal (T), frontal (F) and sagittal (S) plane are given in Table 1. Significant differences were found in movement of the pelvis in the sagittal plane as well as the shoulder in the frontal plane. The position of the pelvis in the sagittal plane (anteversion) also shows differences.

Table 1 Range of movement of the pelvis and shoulder during stride

[°]	Pelvis T		Pelvis F		Pelvis S		Shoulder T		Shoulder F	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Gait	11.03	3.12	7.79	2.13	8.71	1.74	6.94	4.58	4.83	0.68
Riding	8.06	2.44	6.57	1.50	11.49	2.67	8.91	2.76	7.83	2.31

Conclusions
The changes in the crossed body pattern during the gait and during the ride on the horse in hippotherapy are similar. The position of the pelvis during this pattern is different. The motor response of the rider is influenced by the morphology of the horse.

Keywords: *gait, horse, kinematics, pelvis*

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POSTURAL STABILITY AND VISUAL FEEDBACK CONTROL OF BODY POSITION IN PHYSICALLY ACTIVE CHILDREN AND YOUNG INDIVIDUALS

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Introduction
It is known that postural stability is better in healthy adults than in children. However, there is no information about their ability to perceive position of the center of mass (COM) and its regulation in required direction. Therefore the aim of the study was to compare postural stability under various conditions and accuracy of visual feedback control of COP movement in antero-posterior and medio-lateral direction.

Methods
Two groups of physically active individuals, physical education students (n = 26, age 22.1 ± 2.2 y, height 181.4 ± 9.5 cm, weight 72.2 ± 12.4 kg) and children (n = 22, age 9.3 ± 1.4 y, height 140.2 ± 8.3 cm, weight 33.7 ± 7.5 kg) performed static balance tests and task-oriented balance tests. In the first case, subjects were instructed to minimize postural sway by standing as still as possible for 30 seconds under various conditions: bipedal stance with eyes open, bipedal stance with eyes closed, bipedal stance with eyes open on foam, bipedal stance with eyes closed on foam. The velocity of the center of pressure (COP) was registered at 100 Hz by means of the posturography system FiTRO Sway Check based on dynamometric platform. In the second, subjects were provided by feedback on COM displacement on a computer screen while standing on dynamometric platform. Their task was to trace, by shifting COM, a curve flowing either in vertical or horizontal direction. The deviation of instant COP position from the curve was recorded at 100 Hz by means of the system FiTRO Sway Check.

Results
Results showed that the COP velocity was significantly ($p \leq 0.01$) higher in children than in adults during bipedal stance on dynamometric platform with eyes open (21.5 ± 11.6 mm/s and 10.7 ± 1.7 mm/s, respectively) and eyes closed (25.0 ± 13,1 mm/s and 13.8 ± 2.6 mm/s, respectively), as well as on foam surface with eyes open (25.5 ± 12.1 mm/s and 15.2 ± 3.0 mm/s, respectively) and eyes closed (42.4 ± 20.4 mm/s and 37.0 ± 7.8 mm/s, respectively, $p \leq 0.05$). On the other hand, there were no significant differences in mean COP distance from the flowing curve in children and adults, in both vertical (14.2 ± 2.5 mm and 13.2 ± 2.1 mm, respectively) and horizontal direction (15.1 ± 4.1 mm and 14.3 ± 2.4 mm, respectively).

Conclusions
These findings indicate that increasing demand on postural control system during visually-guided COM tracking task does not enable better discrimination between different level of balance capabilities in children and adults shown by conventional static balance tests.

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DEVELOPMENT AND TEST OF THE DTP-3 NONINVASIVE DIAGNOSTIC SYSTEM AND ITS APPLICATIONS IN CLINICAL PRACTISE

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Introduction

Assessment of spinal deformity especially adolescent idiopathic scoliosis is performed by means of radiographic examination with spinal curvature evaluation according to Cobb method. Although radiography is the golden standard in orthopedic practise, it carries the health risk of exposure to ionizing radiation. Radiography is not suitable for screening of spinal deformity at an early stage and is risky when used for repeated monitoring after conservative or surgical therapy. Various examination methods enabling noninvasive spinal curve assessment have been developed. Any such method has not got at widespread use in clinical practise yet. The problem is still low correlation of noninvasive spinal curve measures compared to the standard radiographic Cobb angles.

Methods

The DTP-3 diagnostic system was developed at the Faculty of Physical Culture primarily for noninvasive assessment of spinal deformity and faulty posture. The technical principle lies in the three-dimensional (3D) scanning of points on the skin surface (e.g. acromions, posterior superior iliac spines, spinous processes) by means of a mechanical pantograph with three incremental encoders. The acquired data is transmitted into a PC and the points can be displayed on graphs (3D graph, 2D graphs in the frontal and sagittal planes). In case of the curve assessment, a special software calculates the curvatures of the cervical, thoracic and lumbar spine in both frontal and sagittal plane. The basis of calculation is fitting the six degrees polynomial to measured points and calculation the slope of normal lines in the inflexion points. The DTP-3 system also enables a measurement of back surface in a dynamic mode thus a spinal rotary assessment can be involved. A posture standardization of examinee by means of a newly developed fixation frame that reduces the postural sway was proposed.

Results

The outcomes of DTP-3 examinations were compared to the outcomes of radiographic examination. Firstly, a special model of the human spine was examined for safety reason because the radiographic examination was repeated in different projections. Differences between DTP-3 and radiographic outcomes do not exceed the value of 1.5 mm for linear measures and the value of 5 degrees for angle measures. A group of 14 patients with scoliosis ranging from 10 to 40 degrees was examined for preliminary analysis of the clinical value of the DTP-3 system. The DTP-3 angle outcomes compared to radiographic Cobb angles do not exceed the value of 6 degrees. A research project in which spinal shapes of healthy subjects are examined has been started because only fractional information about range and variability of spinal shapes in current population is known. Currently, more than 800 students of Palacký University have been examined. The spinal shape examination is performed only by means of the DTP-3 system for health safety reason.

Conclusions

The DTP-3 system as other noninvasive examination technique is not able to display the internal structure of the tissue therefore the radiography is still unsubstitutable in the orthopedic practise. The DTP-3 system is not intended as a radiography replacement rather it is an alternative that is suitable for screening of spinal deformity and for frequently repeated examination of progressive deformity especially in adolescent population.

Keywords: *noninvasive curve assessment, spinal deformity, approximation polynomial, population norm*

Acknowledgements: This research study was supported by grant of the Czech Science Foundation – GACR, No 202/09/P029, entitled "Creation of model and population norms of spine shape diagnosis using DTP-3 system in selected peer group".

PRE- AND POST-EXERCISE DYNAMIC BALANCE IN AEROBIC GYMNASTICS

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Introduction

There are several sports where static and/or dynamic balance is one of the limiting factors of athletes performance. Its impairment can not only affect the outcome, but may also increase the risk of injuries [1, 2]. Several follow-up research [3, 4] supported by the observation in the training process and competitions also confirmed that balance in aerobic gymnastics is one of the limiting factors of athletic performance. Its optimal level is an important factor in the implementation of dynamic balance exercise with lots of turns and rotation, as well as maintaining stability in different rebounds during performance [5, 6]. Therefore, rapid readjustment of balance after sport-specific exercise to baseline is considered an important ability.

Methods

A group of 8 junior aerobic gymnasts (aged 16.6 ± 1.9 years, height 162.6 ± 4.2 cm, weight 53.3 ± 3.4 kg) volunteered to participate in the study. All of them were informed of the procedures and of the main purpose of the study. We applied the following tests: 1. Tandem Walking Backward (Tandem1); 2. Tandem Walking Backward after three consecutively performed 360° turns (Tandem2); 3. Tandem Walking Backward after three consecutively performed illusions (Tandem3). Ordinary statistical methods, including average and standard deviation, were used. A Wilcoxon test was employed to determine the statistical significance of differences, $p \leq 0.05$ was considered significant. Spearman's rank correlation coefficient was used to determine statistical dependence between two variables.

Results

The results of dynamic balance showed significantly higher level in comparison with the normal population. We have seen a statistically significant difference ($p \leq 0.05$) between tests Tandem1 and Tandem2 as well as Tandem1 and Tandem3. There is slight indication of linear relationships between Tandem1 and Tandem3. Significant correlation was found between Tandem2 and Tandem3.

Conclusions

Therefore, additional work is required to investigate the causes and consequences of post-exercise balance impairment, to design exercise programs for balance improvement and to develop methods for its assessment.

Keywords: *aerobic gymnasts, dynamic balance, sport-specific elements*

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HUMAN PHYSIOLOGICAL HAND TREMOR RESULTS MAINLY FROM RESONANCE WHICH CHANGES DURING SLOW VOLUNTARY MOVEMENTS

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Introduction

Physiological postural hand tremor typically has a peak frequency around 8 Hz. This component is related to mechanical resonance [1, 2, 3]. However, other factors (central or reflex oscillators) are said to play a part in tremor. In this series of experiments we investigate the relationship between the EMG (the input) and the acceleration (the output). The resulting cross spectral gain spectrum shows conclusively that the main cause of tremor is the mechanical properties of the muscles and limb. Furthermore, for the first time, we show that the characteristics of the resonance and the tremor change greatly during slow movement.

Methods

A visual tracking task was used to regulate the subject's hand position. Hand tremor (miniature single axis accelerometer ICS 3021, EuroSensor UK) and associated surface extensor EMG (Delsys) were recorded for 60 s epochs. Three different static positions and four different velocity slow movement conditions were studied in 10 healthy subjects, 1 female, mean age 23.

Results

The EMG spectrum was generally flat apart from an obvious peak at the frequency of movement in the dynamic conditions and a broad hump of activity in most subjects between 10 and 20 Hz in all conditions. The acceleration spectrum had a clear peak below 10 Hz in every condition. The gain between EMG and acceleration (Fig. 1) showed a distinct peak at the tremor frequency in every trial. In the three postural conditions the peak frequencies were the same. In the four moving conditions the gain peak was much bigger and the frequency of the peak was lower, reducing further as movement became faster.

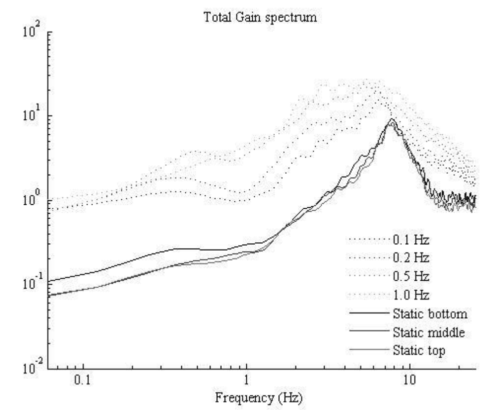

Figure 1. Gain (EMG: Acceleration) in the 7 different conditions.

Conclusions

Postural hand tremor at ~8 Hz reflects the resonant properties of the hand, not the spectrum of the EMG. During movement the resonant frequency of the hand reduces and therefore tremor frequency decreases. There is a very large increase in the size of the tremor which suggests that the damping has also decreased.

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TWO ASPECTS OF THE FEED-FORWARD CONTROL OF VERTICAL POSTURE

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Introduction

We used the idea of multi-muscle synergies and the framework of the uncontrolled manifold hypothesis [3] to explore two aspects of postural preparation to action and to perturbation, anticipatory postural adjustments (APAs) and anticipatory synergy adjustments (ASAs). The former are typically defined as early changes in averaged across series of trials patterns of electromyographic (EMG) signals that are seen about 100 ms prior to the action initiation [4]. The latter are defined as changes in co-variation across trials among variables computed based on the EMG signals that are seen 100-200 ms prior to the action initiation. Until recently, ASAs have only been documented in studies of multi-digit quick and accurate force production tasks [5, 6].

Methods

In a series of experiments, we studied how standing persons prepare to (1) a quick voluntary action by the arms, (2) a quick voluntary body sway, (3) a predictable external perturbation. Early changes in postural muscle activation levels could be seen 400-500 ms prior to the action in experiment (2) and prior to the perturbation in experiment (3), similar to the patterns seen in preparation to stepping [1]. Typical APAs were seen about 100 ms prior to the action initiation in experiment (1) and prior to the perturbation in experiment (3). We quantified multi-muscle synergies stabilizing the average across trials time profile of the center of pressure coordinate in the anterior-posterior direction. Synergies were defined as co-varied adjustments in the magnitudes of muscle modes (M-modes, elemental variables defined within the muscle activation space using principal component analysis with factor extraction) across repetitive trials at comparable times with respect to action initiation or perturbation time.

Results

During steady-state standing, there were strong synergies stabilizing the center of pressure coordinate. The index of these synergies dropped about 100 ms prior to any visible changes in the averaged across trials levels of muscle activation. These ASAs were clearly seen in experiment (1) prior to APAs and in experiment (3) prior to both early postural adjustments and APAs.

Conclusions

We suggest that the purpose of early postural adjustments is to optimize posture for the expected action/perturbation. In contrast, the purpose of APAs is to generate forces and moments of force against those expected from the action/perturbation. ASAs attenuate synergies stabilizing center of pressure coordinate and thus facilitate its planned shift. The findings fit naturally a hierarchical scheme with synergic few-to-many mappings at each level of the hierarchy based on ideas of control with referent body configurations [2]. Two types of control variables are assumed, associated with changes in magnitudes of performance variables and with changes in their stability properties.

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BALANCE CONTROL IN ELDERLY WOMEN WITH OSTEOPENIA AND OSTEOPOROSIS

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Introduction

Postmenopausal osteopenic and osteoporotic women are at increased risk for skeletal fractures [1]. Falls and fall-related fractures are a common event and serious public-health problem facing older adults and are associated with considerable morbidity and mortality [2, 3]. Osteoporotic fractures cannot be completely explained only by skeletal, but also by nonskeletal factors such as body sway and postural instability. Impairment of balance control, often prompting a fall, was pointed out as one of the risk factors [4]. The aim of the study was to compare balance control in healthy and osteopenic/osteoporotic women.

Methods

A group of 25 elderly osteopenic (n=15, T-score of hip and/or spine between -1 and -2.5) and osteoporotic (n=10, T-score of hip and/or spine < -2.5) women (age 70.5±5.6 yrs, height 1.6±5.9 m, weight 65.8±12.7 kg) and 19 healthy age-matched female controls (age 72.0±5.2 yrs, height 1.6±6.3 m, weight 64.8±8.6 kg) participated in the study. Subjects stood quietly under the four static conditions: at stance on a firm and on a foam surface (thickness 10 cm) with eyes either open or closed. Each trial was performed 50s. Body sway was recorded by a force platform and quantified by displacement of the centre of foot pressure (CoP) in the forward-backward (FB) and left-right (LR) direction. Trunk tilts were measured by two ADXL203 dual-axis accelerometers attached on the upper trunk (Th4) and lower trunk (L5). Parameters Ax (amplitude of postural sway in LR direction), Ay (amplitude of postural sway in FB direction) and RMS (root mean square) were evaluated. Data were statistically analyzed using 2-way repeated measures ANOVA and Student´s t-test, $p < 0.05$ was considered significant.

Results

The results showed evident balance impairment in osteopenic and osteoporotic women. We found that amplitudes and RMS (root mean square) of CoP displacement and of trunk tilts were significantly different when comparing elderly healthy women and women with osteopenia/osteoporosis especially during the stance with eyes closed. Analysis of variance showed significant influence of osteopenia/osteoporosis on parameters Ax and RMS recorded by the force platform (CoP) and also by accelerometer placed at upper trunk (Th4). We also observed significant effect of Vision and Surface on all measured postural parameters at CoP, Th4 and L5 levels and their significant interaction. Statistically significant effect of triple interaction Vision x Surface x Osteopenia/osteoporosis on parameters Ax and RMS was found at CoP and upper trunk (Th4). For CoP, upper (Th4) and lower (L5) trunk, subsequently Student´s t-test showed statistically significant increase of RMS values in the group of osteopenic/osteoporotic women during the stance with eyes closed.

Conclusions

Results of our study showed that slight postural instability and impaired balance control occurred in elderly women with osteopenia and osteoporosis. This fact was approved increased values of postural parameters particularly in stance with absence of vision or with the alteration of somatosensory input.

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INTERMITTENT CONTROL: HOW CAN WE IDENTIFY IT?

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Introduction

Sustained control of position and movement is usually explained by continuous feedback mechanisms acting according to central, task related settings of equilibrium position, threshold and feedback gain. An unproven hypothesis is that sustained control might proceed by serial ballistic actions [1, 3]. In the absence of a proven methodology capable of distinguishing serial ballistic from continuous control, this hypothesis and debate has remained unresolved for 60 years [1]. Our aim is to develop a methodology suitable for discriminating human control. The first step here is to test discrimination of serial ballistic from continuous control in an artificial controller whose properties are known.

Methods

Using simulation in a Matlab environment, loads of zero, first and 2nd order were controlled by three controllers, one continuous, one event driven intermittent control and one clock driven intermittent control [2]. Ten, randomly generated, double step disturbances, with 32 double steps over 200s, in which the inter-step interval varies from less than to greater than the expected intermittent or open loop interval [4] were applied to the set point. We then fit an appropriate order, zero delay, ARMA (autoregressive moving average) model relating the control signal to the disturbance. We then reconstructed the disturbance signal by sequentially and individually adjusting the instant of each step to optimise the fit of the ARMA model. This produces an estimate of the delay or reaction time for every 1st and 2nd step stimulus. The delay to the second step was tested for a significant linear relationship with lower inter-step intervals (Fig. 1). When the relationship was significant, the intermittent interval was calculated from the difference between the intercept and reaction time for large inter-step intervals. The method was tested by applying increasing amplitudes of random noise to the control signal.

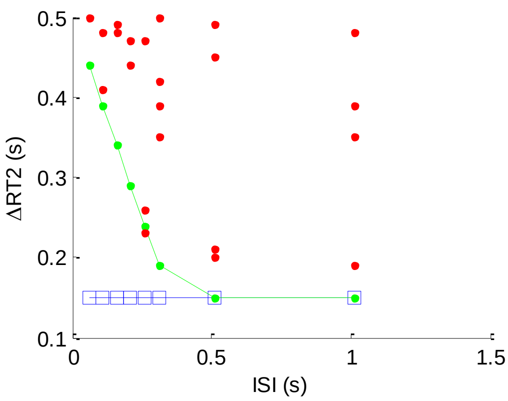

Figure 1. Reaction Time 2 v Inter-step interval. For a zero order load, the estimated second reaction times are shown for a continuous predictive controller (squares), event driven intermittent controller (joined dots) and clock driven intermittent controller (dots).

Results

Event driven intermittent control showed a significant relationship ($p<0.05$) for individual trials between reaction time 2 and inter-step interval for all load orders at all noise levels except the highest level tested for load orders 1 and 2. Continuous control and clock driven control showed no linear relationship between reaction time 2 and inter-step interval for individual trials.

Conclusions

This method can distinguish event driven from control from that which is either continuous or clock driven intermittent. To provide evidence of intermittent control, experiments on humans should be designed to ensure that control trajectories show evidence of being triggered at the first step stimulus.

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MILD COGNITIVE IMPAIRMENT AS A PREDICTOR OF FALLS IN COMMUNITY-DWELLING OLDER PEOPLE

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Introduction
The incidence of falls in people with cognitive impairment with or without a formal diagnosis of dementia is estimated to be twice that of cognitively intact older adults, however, the relation between mild cognitive impairment (MCI) and falls is less clear. The aim was to investigate whether MCI is associated with falls in older people.
Methods
419 nondemented community-dwelling adults aged 70 to 90 years, participating in the Sydney Memory and Ageing Study, underwent a comprehensive neuropsychological test battery measuring four cognitive domains, and were classified being with or without MCI based on objective published criteria [1]. Assessments of medical, physiological and psychological measures were also performed. Fallers were defined as people who had at least one injurious fall or at least two non-injurious falls during a 12-month follow-up period [2].
Results
342 (81.4%) participants had normal cognitive functioning, 58 (13.8%) had non-amnestic MCI and 19 (4.5%) had amnestic MCI. People with MCI performed worse than people without MCI in measures of general health and balance ($p \leq 0.05$). Logistic regression analyses showed that fall risk was significantly greater in people with MCI (OR=1.72, 95%CI=1.03 to 2.89). This association was stronger when the analysis was restricted to those with non-amnestic MCI (OR=1.98, 95%CI=1.11 to 3.53), where the relationship was mainly explained by impaired executive functioning (OR=1.27, 95%CI=1.02 to 1.59). These associations remained significant after adjusting for potential confounders (Table 1).
Conclusions
The findings indicate that objectively defined MCI is an independent risk factor for injurious or multiple falls in a representative sample of community-living older people. The presence of non-amnestic MCI, based primarily on executive function, was found to be the most important factor in increasing fall risk.

Table 1 Logistic regression models relating to odds of suffering multiple or injurious falls over 12 months for MCI categories

Section	OR(95%CI) §
MCI (yes)	1.54 (0.90-2.63)
Amnestic MCI (yes)	0.85 (0.28-2.57)
Non-amnestic MCI (yes)	1.82 (1.00-3.31) *
Attention domain composite z-score	1.02 (0.81-1.28)
Language domain composite z-score	1.17 (0.92-1.50)
Exec function domain composite z-score	1.23 (0.97-1.55) ^
Memory domain composite z-score	0.90 (0.71-1.13)

Note: § controlling for Age, Education, PPA, WHODAS and medication use * $p \leq 0.05$, ^ $p \leq 0.10$

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RELATIONSHIP BETWEEN BALANCE CONTROL AND STRENGTH IMBALANCES IN ELITE JUNIOR SOCCER PLAYERS

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Introduction

Since the game of soccer frequently involves one-sided activities such as kicking, tackling and passing, asymmetries in muscle strength between both legs are possible. Low balance ability is generally associated with an increased risk of ligament injuries, and the detection of a possible asymmetry in balance is important because a bilateral difference may be a contributing factor to injury [1]. The aim of the study was to compare the balance abilities and muscle strength asymmetries (hamstring:quadriceps ratio, H:Q) of the preferred (PL) and nonpreferred leg (NL) in elite junior soccer players.

Methods

The monitoring was carried out with fourteen Czech junior elite male soccer players (silver medal from European championship 2011), category U19 (age 18.6±0.2 years, height 178.6±5.5 cm, weight 73.3±6.9 kg). Total travel way (TTW) of centre of pressure as an indicator of postural stability was assessed by force plate Footscan with frequency of 33 Hz. The length of the tests was 60 s for one leg standing position for each leg was measured. Isokinetic strength of knee extensors and flexors on both lower extremities during concentric contraction in $60°\cdot s^{-1}$ angular velocities was assessed by dynamometer Cybex Humac Norm (Cybex NORM ®, Humac, CA, USA). Pearson's correlation analysis was carried out for finding relationships between parameters. The comparison of TTW and H:Q ratios between the PL and NL were carried out using the Student's t-test.

Results

We found significant difference in level of TTW between PL and NL in elite junior soccer players (TTW_{PL}= 942.9±168.9 mm, TTW_{NL}= 1136.5±251.9 mm, $t_{(13)}$= -3.73, $p<0.01$). Results of study did not reveal significant difference between H:Q ratio of both legs ($H{:}Q_{PL}$= 59.3±5.1 mm; $H{:}Q_{NL}$= 59.1±8.5 mm; $t_{(13)}$= 0.10, $p>0.05$). We found significant correlation between TTW_{PL} to $H{:}Q_{NL}$ (r = -0.62, $p<0.05$), but no for PL (r = 0.25, $p>0.05$). Relationship between TTW_{PL} vs. TTW_{NL} was also significant (r = 0.64, $p<0.05$).

Conclusions

In our investigation we found the higher level of postural stability in preferred leg with comparison to nonpreferred leg (17%). From point of view individual approach, the higher occurrence of ipsilateral strength assymetries (H:Q ratio) we found in favour of nonpreferred leg. Significant correlation between TTW and HQ in nonpreferred leg is indicate the common reason for observed parameters. The poor balance control and strength asymmetries in nonpreffered leg maybe of reason higher risk of injuries of elite soccer players. Two players reached lower values of H:Q ratio than critical value for professional players (0.47) at velocity of $60°\cdot s^{-1}$,which means a risk muscle imbalance [2]. Monitoring of balance control and strength asymmetries at the beginning of the preparatory period enables identification of possible weaknesses of fitness level, which should be further reduced during the preparatory period. Screening examination of balance control and strength imbalances may be thus a useful tool for prevention of muscle injuries in soccer players.

Keywords: *elite sport, posture control, football, health*

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MODELING THE HUMAN REMNANT DURING MANUAL CONTROL TASKS

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Introduction

When a human operator controls a system which is excited at certain discrete frequencies, the output response contains information both at excited and non-excited frequencies. The output signal at non-excited frequencies is called remnant. In early attempts to model human remnant during simple manual compensatory tracking tasks it was described as observation noise which is independent of the controller function [1]. Although the above model is treated as a paradigm, there is ongoing debate on the characteristics of the inherent noise that is revealed during manual motor tasks [2]. An alternative explanation of remnant is that it is inherent to the controller structure, rather than caused by an external noise source.

In recent work we have shown that intermittent control (IC) may be an alternative description of human control [3]. In this study, we extend our previous pilot experiments [4] and investigate, whether remnant can be described as an intermittent controller with random intermittent interval, or whether the traditional description with a predictive controller (PC) with added white noise is more suitable.

Methods

Two controller models, a linear PC with added white noise and an IC with random intermittent sampling interval, were used to fit the remnant signal derived during a motor control task. Eleven subjects were asked to control a second order unstable system with a joystick while it was perturbed by a periodic multisine signal [5]. Initial controller parameters were obtained for the case without added noise (PC) and for fixed intermittent intervals (IC). Frequency domain approximations of the remnant signal of the experimental data were then derived by varying the standard deviation of the added white noise (PC) and of the standard deviation of the random intermittent sampling interval (IC), respectively. For each subject, the best fit was determined as the minimum cost function (the mean-squared difference between the remnant signal and the control signal derived from the simulation models at non-excited frequencies). The mean value across all subjects was generated for both controllers, together with the corresponding standard deviations of the added noise and of the intermittent interval, respectively.

Results

For the IC with random intermittent interval we obtained a best fit of 2.9±3.8 [10^{-6}] (mean±SD) at a distribution of the intermittent intervals of 0.47±0.29, while for the PC the best fit was 4.7±6.9 [10^{-6}] with a noise standard deviation of 0.09±0.05.

Conclusions

This study shows that intermittent control can explain human remnant during a manual control task without the need for an external noise source. The remnant is due to the random intermittent sampling process in the controller, rather than a white noise source with specific characteristics as required with a predictive control model.

Keywords: *human motor remnant, predictive control, intermittent control*

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POSTURAL IMBALANCE IN PARKINSON'S DISEASE AND PROGRESSIVE SUPRANUCLEAR PALSY

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Introduction

Postural imbalance and falls are cardinal symptoms in patients suffering from neurodegenerative diseases involving the basal ganglia such as Parkinson's disease (PD) or progressive supranuclear palsy (PSP). Other than in PD patients, postural instability and falls in PSP patients are more severe and earlier in the course of the disease. However, whether these abnormalities in PSP are just more pronounced or whether they are qualitatively different is still open to debate. We examined spontaneous and externally disturbed upright stance and compared subjects' behaviour in order to characterize the deficits associated with each disease.

Methods

18 PSP patients, 12 PD patients and 18 healthy control subjects participated in the following experiments. Posture analyses and clinical assessments were performed in the Department of Neurology of the Ludwig-Maximilians-University Munich. Subjects stood as natural as possible upright on a custom-built motion platform to investigate unperturbed and perturbed stance. Each trial consisted of about 2 minutes. Subjects stood either with eyes open or eyes closed. We explored subjects' spontaneous sway as well as their postural responses to transient tilts of a motion platform in the anterior-posterior direction. After a period of more than 30 sec of spontaneous standing the stimuli were applied for about one minute, followed by another period of spontaneous sway at the end of the trial. Stimulus design was based on a pseudorandom ternary sequence of numbers. The tilt axis was through the ankle joints. Peak to peak amplitude was either 0.5 or 1° symmetrically distributed about the axis of rotation with equal degrees of tilt in forward and backward directions (3 repetitions per amplitude). We recorded the anterior-posterior centre of pressure (COP) sway path with the help of a torque sensor in the axis of the rotating platform. Furthermore, we measured the position of different body segments using an ultrasound positioning system (Zebris). Markers were placed on the head, shoulders, vertebral spine, pelvis and knees. These data were stored on a PC for offline analysis. From these data we extracted the standard deviations of the COP linear excursions in AP direction, and lower body and upper body angular and linear excursions in anterior-posterior and in medio-lateral directions which corresponds to sagittal and frontal planes, respectively. Further, we calculated Fourier transforms of these excursions to get transfer functions of the segmental behaviour (MATLAB, The MathWorks Inc., Natick, MA, USA). Displacement, velocity and frequency of sway were quantified through identification of the parameters presented in Maurer et al. [1]. Statistical significance was tested by analysis of variance (ANOVA) and post-hoc tests.

Results

Whereas spontaneous COP excursions in PSP patients were smaller compared to PD patients, excursions of the hip and shoulder were larger in PSP patients compared to PD patients. Velocity of the COP, the hip and the shoulder excursions were lower in PSP patients compared to PD patients. During platform tilts with eyes open, the gain and phase values of patients' motor reactions were not much different from healthy subjects' behaviour, apart from a different strategy for trunk movements. Whereas healthy control subjects tend to align the trunk with an earth vertical, PD and PSP patients' trunk showed larger inclinations. With eyes closed PSP patients showed enormous responses of the trunk, whereas PD patients responses of the trunk where in the order of their eyes-open behaviour.

Conclusions

The new and clinically relevant finding of this study is that imbalance in PSP is different from that in PD patients. The major difference lies in the motor behaviour of the upper body. In addition, PSP patients' motor behaviour depends on the sensory inputs available, whereas PD patients' behaviour is almost independent from available sensory cues. We conclude that PSP patients' imbalance is not just a more pronounced deficit compared to PD patients. In contrast, PSP patients show additional deficits, which cannot be found in PD patients, pointing to an additional source of imbalance in PSP patients.

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HOW DOES WALKING WITH (OR AGAINST) A METRONOME BEAT AFFECT GAIT?

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Introduction

Walking to a steady beat may increase step time variability [1], and it disrupts the long-term 'fractal-like' patterns in gait stride variability [2]. The implications of these findings are still being explored, but the intent to follow a steady beat seems to alter the smooth, repeatable nature of gait in some way. Two measures attempting to describe smoothness have previously been applied to movement acceleration data. Jerk Index (JI), using the time derivative of acceleration, indicates 'jerkiness'; JI is higher when finger tapping is paced by a metronome than when subjects tap freely [3]. Harmonic Ratio (HR) compares the acceleration signal's even and odd harmonic components, essentially quantifying the gait cycle's repeatability; it is lower for older subjects or in a dual task condition [4]. In this project we compare the JI and HR of gait a) in time with the beat (synchronized) and b) counter-phase to the beat (syncopated). Our goals are to explore the changes in gait during the challenging syncopated condition, and to better understand the relationship between JI and HR, which to our knowledge have not been directly compared.

Methods

Eleven young, healthy subjects (7 males, mean age 25.8±3.2 years) walked on a quiet street for 20 one-minute trials wearing a McRoberts DynaPort MiniMod portable accelerometer on a waist-belt. They carried an HP iPAQ handheld computer, which used customized software to synchronize the metronome with the accelerometer and calculate appropriate metronome speeds based on the subject's preferred step time in the initial two trials. During these baseline trials no beats were heard; in all other trials the metronome beats were transmitted via earphones. Trials included synchronized and syncopated conditions at three speeds (85%, 100%, 115% of preferred cadence). For synchronized trials, subjects were instructed to try to step in time to the beat, while for the syncopated trials they were instructed to try to step exactly midway between two beats. Analysis of the filtered accelerometer signal (F_s=100 Hz) in the anterior-posterior direction yielded HR and JI. Heelstrike events were extracted from the signal to calculate step time.

Results

With so few subjects to date, the clearest result was high inter-subject variability. Mean and variability of step time did not vary across conditions. However, both JI and HR were higher at the faster speed for both syncopated and synchronized conditions. This result is interesting because, if valid, it indicates that as the subjects went faster they got jerkier, but their strides were more consistent.

Conclusions

Increases in JI have been attributed to a decrease in movement automaticity; HR's relationship to motor control is less clear. More subjects are required to confirm our findings, but we can conclude that while both JI and HR are assessing aspects of gait smoothness, they do not seem to have a clear inverse relationship. Further work with healthy older subjects, perhaps extending also to those with Parkinson's, may more clearly define the interaction of these attributes.

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SENSORY CONTROL OF HUMAN POSTURE AND ITS MODELING

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Experimentally investigating, abstracting and modeling human sensorimotor functions will help us to better understand and improve medical interventions and assistive devices such as deep brain stimulation and neural prostheses. Focusing the approach on human reactive stance control has several advantages. One is that under certain conditions it allows for a simplification of biomechanics (as single or double inverted pendulum). Another reason is that the vestibular sensor, a major constituent of this control, is relatively simple. Our understanding of it owes to studies of other physiological functions (vestibulo-ocular reflex, self-motion perception) as well as to analogies with technical gravito-inertial sensors. Including such additional pieces of knowledge helps the system identification of stance control, which otherwise would represent a major problem due to its multisensory, redundant and adaptive nature.

Focus of our own work is on multisensory integration aspects. It tries to model, for example, the ‘sensory reweighting’ mechanisms that allow the system to flexibly deal ad hoc with changing external disturbance situations. But the modeling should also consider that the human system is versatile in many other respects as well, providing parsimony in energy consumption and computational effort, robustness when facing internal failures (‘fail safe’), possibility for ‘control policy’ (‘response strategy’), help of perception through learning and expectation, flexibility as to the number of body segments used, and successful treatment of noise in the neural signals. This list of relevant aspects is almost frightening because it appears to imply a high complexity of the system. Yet, keeping in mind that simplicity is a goal of evolution, the list should not discourage modeling, but rather constrain and guide it.

I use the list in my talk as a guide to challenge our stance control model in particular and such models in general. Our own model is called *d*isturbance *e*stimation and *c*ompensation, DEC model [1]. It holds that a) four types of external disturbances challenge stance stability (support surface rotation and translational acceleration, field forces such a gravity, and contact forces such as a push) and that b) estimates of these disturbances are extracted from the multitude of balancing situations through online interactions between sensors (vestibular, joint angle and joint torque; vision helpful, but not required). The estimates rather than sensory signals are fed back, using the method of ’disturbance injection (or rejection)’.

The model showed a high describing and predictive power across the several experimental situations we tested so far. It is also versatile in that it lends itself to fusion with proactive (volitional) balancing control and is compatible with the above list. Furthermore, its principles appear applicable to other sensorimotor functions such as to reactive and targeting head and arm movements. Finally, we successfully re-embodied it into a posture control robot (PostuRob), thereby fostering interaction with robotics and the novel interdisciplinary research field of neurorobotics.

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VESTIBULAR CONTROL OF BALANCE WHEN STABILITY IS DIRECTIONALLY-DEPENDENT: VIOLATION OF CRANIOCENTRIC ORGANISATION

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Introduction

Balance responses to vestibular input have been shown to be closely linked to head position, as one would expect given that vestibular input is itself craniocentric. Such behaviour is appropriate if the balance system acts to null vestibular error signals. The magnitude of balance responses to vestibular-input are known to reduce in magnitude when stability is increased. Here we ask what the effect of directional-dependence (anisotropy) in body stability is on vestibular-evoked balance responses. One possibility is that overall response magnitude is modulated according to body stability whilst craniocentricity is maintained. The other possibility is that frontal and sagittal components of the balance response are differentially modulated dependent on anisotropy in body stability. This would lead to violation of a craniocentric organising principle.

Methods

Participants were young adults (19-38) with no history of vestibular or neurological disorder. Current (1 - 2mA) was passed between mastoid electrodes to stimulate the vestibular nerve. Balance responses to both galvanic and stochastic variants of this stimulus were tested. Balance response directions were quantified through the early (~200-400 ms) ground reaction force responses to the stimuli; measurement details are available from recent reports using galvanic [1] and stochastic [2] stimulation. Stance width was varied to modulate the ratio of frontal to sagittal plane stability [3] and balance responses were evoked across a range of head yaw angles. The various combinations of stimulus mode, stance width and head yaw angle were investigated across 3 experiments (n = 11; n = 7; n = 15).

Results

With the feet together there was a linear relationship between head position and balance response direction. When stance width was increased such that the body was significantly more stable in the frontal than the sagittal plane, the relationship between head position and balance response direction became non-linear in a manner predictable from the anisotropy in body stability. The departure from craniocentricity became greater as stance width was progressively increased.

Conclusions

The balance system does not operate by simply nulling vestibular error signals. It appears to assign relatively lesser relevance to components of vestibular input acting in the direction of greater body stability.

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ASSESSMENT OF NEUROMUSCULAR FUNCTION IN PATIENTS AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION: OVERVIEW OF DIFFERENT TESTING PROTOCOLS

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Introduction

The assessment of the neuromuscular function in patients recovering after anterior cruciate ligament (ACL) reconstruction is of essential importance in monitoring the effects of their rehabilitation program. The most often applied tests have been based on the maximum voluntary contraction of a selected muscle group performed under isometric (IM) or isokinetic (IK) conditions. Recently, a group of authors have suggested novel approach, based on the alternative consecutive maximum contractions (ACMC) [1, 2]. The aim of the present study is to compare the outcome of IM, IK and ACMC tests, when used in the assessment of rehabilitation outcome after ACL reconstruction.

Methods

20 athletes (age 25.0 ± 4.9 years; weight 80 ± 14 kg; height 180.0 ± 7.7 cm) were tested using standard IM, IK (60 and 180 deg/s) tests as well as test based on ACMC, before, 4 and 6 months after ACL reconstruction. Peak torque (PT) as dependent variable was derivated from the torque-time curves.

Results

Results of our work are shown in Table 1**.** F-values of the main effects of group and age (factorial ANOVA) and their interaction (*p<0.05, **p < 0.01) are also shown.

Table 1 The outcome averaged across the subjects (mean ± SD) of the applied muscle strength tests

Months	IM PT (Nm)				ACMC PT (Nm)				EXTENSORS	Months	Leg	Interaction
	EXTENSORS		FLEXORS		EXTENSORS		FLEXORS			*df = 2*	*df = 1*	*df = 2*
	Injured	Healthy	Injured	Healthy	Injured	Healthy	Injured	Healthy	IM PT	8.58**	11.8**	2.50
Before	208 ± 54	175 ± 48	106 ± 28	90 ± 18	193 ± 51	161 ± 49	85 ± 27	76 ± 22	ACMC PT	4.16**	16.3**	3.09*
4	192 ± 47	124 ± 40	96 ± 21	81 ± 29	191 ± 44	113 ± 35	92 ± 23	75 ± 23	IK 60 PT	5.11*	13.79**	4.23*
6	209 ± 42	151 ± 33	107 ± 20	91 ± 21	203 ± 42	142 ± 37	94 ± 18	83 ± 20	IK 180 PT	2.04	10.07**	0.876
Months	IK60 PT (Nm)				IK180 PT (Nm)				FLEXORS	Months	Leg	Interaction
	EXTENSORS		FLEXORS		EXTENSORS		FLEXORS			*df = 2*	*df = 1*	*df = 2*
	Injured	Healthy	Injured	Healthy	Injured	Healthy	Injured	Healthy	IM PT	4.20*	3.63	0.007
Before	164 ± 35	122 ± 45	101 ± 20	92 ± 27	126 ± 23	97 ± 29	92 ± 24	77 ± 19	ACMC PT	2.99	2.18	0.857
4	168 ± 35	94 ± 37	102 ± 22	85 ± 30	123 ± 30	81 ± 26	82 ± 16	68 ± 20	IK 60 PT	0.213	3.56	0.314
6	180 ± 37	116 ± 42	108 ± 22	88 ± 29	127 ± 27	96 ± 33	84 ± 15	75 ± 21	IK 180 PT	2.014	3.32	0.216

Conclusions

The outcomes of all four protocols (Tab. 1) indicated changes associated with the rehabilitation program applied over 6 months. However, IK at 60 deg/s as well as the ACMC test were more sensitive when compared with IM and IK at 180 deg/s. In addition, as the ACMC test could be used with less expensive equipment and is easier to administer, one can conclude that ACMC could be developed into standard assessment tool for neuromuscular function in athletes rehabilitating after ACL reconstruction.

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SELECTIVITY OF ATTENUATION AND FACILITATION OF SOMATOSENSORY POTENTIALS DEPENDS ON THE RELEVANCE OF SENSORY INPUTS DURING GAIT INITIATION

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Introduction

A fundamental issue in motor neuroscience is to understand how the brain deals with the massive flow of information generated during movements. It has been recently proposed that the transmission of afferent inputs to the somatosensory cortex is weighted according to the their relevance with regard to the control of movement. Here we directly tested this hypothesis by recording cortical evoked potentials after either stimulation of muscular (Experiment 1) or cutaneous (Experiment 2) receptors from the lower limbs during step initiation. We chose this paradigm because step initiation is known to be essentially controlled through plantar cutaneous cues with little contribution of muscular proprioception. We predicted that the brain will selectively attenuate proprioceptive afferent signals and facilitate cutaneous inputs.

Methods

Seven and nine subjects participated in Experiments 1 and 2, respectively. They stood barefoot with the eyes closed on a force platform. They were instructed to step forward with the right (stepping) leg. In Experiment 1, the tendons of the peroneus longus (supporting leg) and tibialis posterior (stepping leg) muscles were vibrated simultaneously during 1 s when the mediolateral force towards the stepping leg attained 10 N. The vibration induced an afferent volley mimicking the pattern resulting from lateral body tilt in the opposite side to the vibrated muscles (i.e., towards the supporting leg). The experimental procedure of Experiment 2 was identical to Experiment 1 with only one exception; a brief (5ms pulse) electrical stimulation of the foot sole replaced the ankle muscle vibration. The anode was located under the metatarsal region and the cathode was under the heel of the supporting foot [1]. The stimulation was delivered only under the supporting foot in order to elicit cutaneous information related to a change in body weight over the supporting foot (as in Experiment 1). The electroencephalogram (EEG) was recorded from 64 Ag/AgCI surface electrodes.

Results

In Experiment 1, we found that ankle muscle vibration elicited transient and lateralized significant attenuations of the somatosensory evoked potential. In Experiment 2, no sensory gating was observed when plantar sole cutaneous afferents were stimulated. On the contrary, the sensory inputs transmission to the cortex was facilitated.

Conclusions

These observations suggest that the brain exerts a dynamic control over the transmission of the afferent signal (i.e. re-weighting) according to the current relevance of the afferent signals during the execution of gait initiation.

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ENHANCED EXCITABILITY OF TIBIALIS ANTERIOR SPINAL AND SUPRA-SPINAL RESPONSES TO PERTURBATION OF STANCE IN UNILATERAL PARKINSONIAN PATIENTS

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Introduction

During stance, toe-down rotation of a supporting platform evokes a medium-latency response (MLR) in the stretched tibialis anterior (TA). This response is smaller when the perturbation is administered while holding onto a support. In patients with Parkinson's disease (PD), the MLR is decreased by holding to a lesser extent than in normal subjects [1]. These changes can be due to hyperexcitability of cortical or spinal circuits, or both. There is evidence that the MLR consists of two components: one spinal (MLR1), fed by group II spindle afferent fibres through an olygosynaptic circuit [2, 3], and the other supra-spinal (MLR2) [3, 4]. Appropriately conditioning the toe-down perturbation allows to investigate separately the effects of PD on spinal and supra-spinal reflex pathways. Further, since the MLR is sustained by both ipsi- and contralateral input, we separately administered the perturbations to either leg to disclose a potential asymmetry in both components. Moreover, when the disease initially affects one side, one can compare the excitability of the spinal and supra-spinal responses between the affected and unaffected side.

Methods

Ten patients (7 de novo) with unilateral PD (6 women and 4 men, mean age 63.7 years ± 11.3 SD) and 10 normal subjects (NS, 5 women and 5 men, mean age 66.4 years ± 9.1) were administered perturbations as follows: 1. both legs on the platform during free stance (control), 2. same as 1, while holding onto a stable frame, 3. free stance, one leg on the platform and the other off on firm ground. For PD, the single leg perturbation condition was tested with the unaffected and affected limb on the platform in separate trials.

Results

1. Control: the area of MLR1 and MLR2 of both limbs was not different between PD and NS.
2. Holding: MLR1 shrank to 40% of free stance in NS. In PD, the response shrank to a similar extent in the unaffected limb but to only 60% in the affected limb ($p<0.01$). The MLR2 of PD behaved similarly to NS.
3. Unilateral: the ratio of MLR1 Leg-off/Leg-on in NS and PD was 40% and 55%. The ratio of MLR2 was 70% in NS or in the unaffected limb of PD, whilst it was 100% in the affected limb ($p<0.05$).

Discussion

No changes in MLR are obvious when simultaneously perturbing both legs of unilateral PD patients. However, MLR1 was aymmetrically modulated by holding, suggesting that the control of the ipsilateral contingent of the descending monoaminergic modulatory pathways is deficient in PD [5]. The minor changes of MLR1 during unilateral perturbation point to a preserved spinal group II circuits; conversely, the larger MLR2 in the affected than unaffected leg suggests a disinhibition of the supraspinal component of the response.

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THE RAPID NEURAL RESPONSE TO SLOW PLATFORM TILTS IN STANDING MAN

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Introduction

Gurfinkel et al. [1] have previously described the reactions of standing human subjects to slow tilts of the support surface. Averaged records showed that a constant velocity platform tilt of 0.05°/s initially resulted in a relatively fast body inclination in the direction of the tilt. After a period of around 3-5 seconds, stronger resistance to body inclination began. Gurfinkel et al. suggested the cause of this initial body deviation was due to mechanical yielding of the calf muscle/tendon/joint unit under conditions of support surface tilt. Neural intervention occurred only as the body slowed after the initial inclination. The recent discovery [1, 2] that ankle stiffness is inadequate on its own to provide stable standing has lead us to reinvestigate this behaviour.

Methods

Subjects (n = 5; 3 male) stood quietly with eyes closed on custom built footplates controlled by a servo motor which generated slow rotations in the sagital plane around the axis of the ankle joint. Trials consisted of a baseline period followed by a constant velocity (0.05°/s) toes-up or toes-down tilt lasting 10 seconds. We combined high quality ultrasound imaging of the soleus and gastrocnemius muscles with a novel automatic tracking technology to provide a continuous measure of muscle length change for the duration of the initial response. Ankle and platform angles were measured by laser retroreflective rangefinders and surface EMG recorded from the soleus and gastrocnemius muscles.

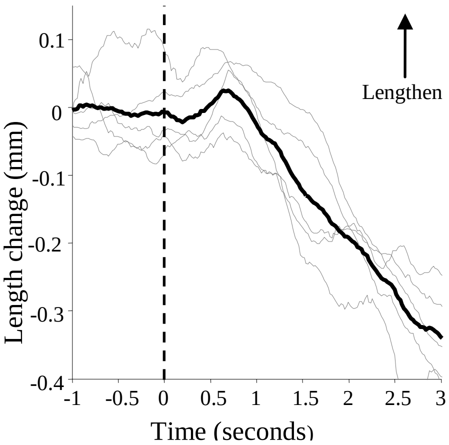

Figure 1. Soleus muscle length responses to a slow 'toes down' tilt of the support surface. Each subject mean is plotted as a grey line. The group mean is plotted as a full black line. The tilt onset is shown by the vertical dashed black line.

Results

Our averaged results for a toes down tilt showed the expected fast initial forward body deviation. This was accompanied by a shortening of the soleus (Fig.1) and gastrocnemius muscles. Conversely, toes-up tilts resulted in a corresponding backward body inclination accompanied by a lengthening of the calf muscles. Changes in calf muscle EMG were observable within 500 ms of the start of the ramp.

Conclusions

Mechanically, the calf muscles would be expected to lengthen as the body leant forwards, and shorten as the body leant backwards. Our results show the opposite demonstrating that neural rather than purely mechanical processes are involved in the initial response to slow support surface tilts.

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VESTIBULAR SIGNALS FOR ORIENTATION DURING SELF-GENERATED HEAD MOTION

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Introduction
Vestibular signals contribute to our sense of orientation [1]. But as the end organs are locked within the skull, an identical signal can indicate different whole body motion depending upon head orientation. The vestibular signal must be transformed from head coordinates to earth coordinates in order to sense whole body orientation. Although this transformation process has been demonstrated during static head orientations [2], it is unclear if it remains effective during self-generated head motion. In this case, the CNS must distinguish vestibular exafference from reafference.

Methods
Galvanic vestibular stimulation (GVS; for review see [3]) was used to induce an exafferent signal of head roll in blindfolded subjects stepping in place while attempting to maintain a constant whole body orientation. In Experiment 1 subjects concurrently maintained static head orientations. In Experiment 2 subjects self-generated a prescribed head movement profile (see Figure 1B), thus introducing a reafferent vestibular signal.

Results
In Experiment 1, GVS evoked whole body rotation in a direction strongly affected by head pitch ($F_{4,44}$=12.3, p<0.001). Rotation was towards the anode with the head pitched down (1.8±0.9°/sec at –32±8° pitch; mean±SD; positive velocity indicates anodal direction), minimal with the head approximately level, and reversed direction with the head pitched up (-0.1±0.7°/sec at 35±5° pitch). In Experiment 2, head pitch again had a significant effect on turning velocity ($F_{2,22}$=6.4, p=0.019). Rotation was continuously modulated throughout self-generated head motion (see Figure 1). In 8 of 12 subjects this modulation was sufficient to completely reverse the direction of rotation.

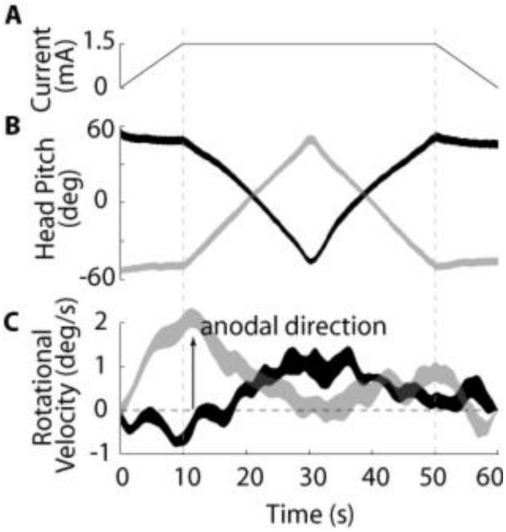

Figure 1. A) GVS current; B) Head movement profiles; C) GVS-evoked whole body rotation (mean±SEM; black and grey traces show trials starting with head up and down, respectively).

Conclusions
These results demonstrate successful transformation of vestibular signals from head coordinates to earth coordinates during self-generated head motion. This provides behavioural evidence that the CNS is able to distinguish vestibular exafference from reafference. This explains why self-generated head movements can be made without losing the sense of orientation.

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MODEL-BASED INTERPRETATIONS OF HUMAN BALANCE RESPONSES TO SIMULTANEOUS VISUAL-TILT AND SURFACE-TILT STIMULATION

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Introduction

In previous work we developed an "independent channel" (IC) feedback control model of human balance that accounted for the regulation of center of mass (CoM), sagittal-plane, angular body sway evoked by pseudorandom rotations of either the support surface or visual surround [1, 2]. The model assumed that sensory integration could be represented as a linearly weighted combination of visual, proprioceptive and vestibular orientation information. Following a single time delay, representing all delays in the system, a "neural controller" generated corrective ankle torque as a function of the combined sensory orientation signal. Results showed that sensory channel weights, estimated from curve fits of model equations to experimental frequency response function (FRF) data, varied as a function of the visual-tilt or surface-tilt stimulus amplitudes. At any particular stimulus amplitude, the sensory weights were fixed values. Therefore, the IC model is essentially a linear system model. If this model accurately represents the balance control system, then the model should be able to account for CoM responses to arbitrary combinations of visual and surface stimuli even if these stimuli are uncorrelated with one another. We gathered a large data set of CoM responses to visual stimuli, surface-tilt stimuli and combinations of simultaneously presented visual and surface stimuli to determine (1) if the IC model could account for all of this data or if more complex models were required, and (2) if responses to visual and surface stimuli were truly independent of one another or if there were interactions between the visual and surface stimuli when they were presented simultaneously.

Methods

CoM sway data were collected from nine healthy subjects standing eyes open and responding to pseudorandom visual and/or surface-tilt perturbations that evoked sagittal plane sway. Each subject performed 24 tests that included 4 visual-only stimuli (1, 2, 4, 8° peak-peak amplitudes), 4 surface-only stimuli (1, 2, 4, 8° peak-peak amplitudes) and 16 dual stimuli (simultaneous visual and surface stimuli with all combinations of 1, 2, 4, 8° peak-peak amplitudes). For dual-stimuli tests, the pseudorandom stimuli for the visual and surface perturbations were mathematically uncorrelated with one another. Fourier analysis was used to calculate 40 experimental FRFs (2x16 for dual-stimuli tests+8 for single-stimuli tests). Optimization methods were applied to estimate parameters (sensory weights, neural controller, time delay) of the IC model that provided the best possible fit to the full set of experimental FRFs. Optimal fits were also performed for numerous other models that were more complex than the IC model to determine if additional model complexity was needed and justified to account for the FRF data. These other models included stretch reflex pathways, more complex representations of muscle/tendon mechanics, separate time delays in sensory feedback loops and separate neural controller for each sensory feedback.

Results

The IC model accounted for the major features of FRFs from both single- and dual-stimulus tests. Visual sensory weights decreased with increasing visual stimulus amplitude and proprioceptive sensory weights decreased with increasing surface stimulus amplitude for both single- and dual-stimulus tests. However, there were interactions seen on dual-stimulus tests in that, at a given visual stimulus amplitude, the visual channel weight increased with increasing surface stimulus amplitude. Similarly, at a given surface stimulus amplitude, the proprioceptive channel weight increased with increasing visual stimulus amplitude. Moreover, some models that were more complex than the IC model provided better overall fits to the FRF data based on reduction in mean squared error between model-derived FRFs and experimental FRFs. The additional model complexity appeared to be justified based on criteria (Akaike and Bayesian information criteria) that balance the reduction in mean squared error with the addition of model parameters. Our most successful model included separate time delays for each sensory system and separate neural controllers to convert each sensory system's orientation signal into a component of the overall corrective torque.

Conclusions

Each model we considered represents a different hypothesis regarding how the nervous system processes sensory orientation information and generates motor actions for balance control. The IC model effectively hypothesizes that the sensory integration process is separate from the process that generates motor commands based on the combined sensory information. However, our experimental data was better explained by a more distributed model where sensory integration and motor processing are less separable from one another.

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RELATIONSHIP BETWEEN POSTURAL STABILITY AND ATTENTION IN PREPUBESCENT CHILDREN

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Introduction

Although postural stabilization has been considered an automatic controlled task, the recent studies based on the dual-task paradigm have suggested that there are significant attentional requirements for postural control [1]. Using the dual-task paradigm, a role of attention for postural stabilization is investigated under the condition of a concurrent additional cognitive activity. There is the question whether postural stability can be affected by a level of subject´s attention while performing a single balance task. Therefore the aim of the study was to investigate the relationship between a level of the balance and the different aspects of attention in prepubescent children.

Methods

Two groups of 11-15 years old children with and without developmental deficit of balance (BAL-, n=8, 5 boys, 3 girls; BAL+, n= 24, 13 boys, 11 girls) were selected on the base of testing with three balance tests of the Movement Assessment Battery for Children-2 (MABC-2) [2]. Besides the balance testing, both groups performed the d2Test of Attention [3] to assess the attention by means of the following indicators: the quantity of attention performance, total attention performance and performance of concentration of attention. Significance of differences of the group means was tested with Cohen´s effect size coefficients d and the t-test ($p<0.05$). Relations between the balance and attention indicators were tested with Pearson correlation coefficients r ($p<0.05$).

Results

The deficit of the balance of the Bal- group was associated with the significant lower performance in static balance (Bal1 test) and dynamic balance during walking backwards (Bal2 test). Performance of concentration showed to be significantly higher in the BAL+ group as compared to the BAL- group while quantity of attention performance and total attention performance did not (Tab. 1).

Table 1

Indicators of the balance	BAL- (M ± SD)	BAL+ (M ± SD)	d	t-test (p-value)	Indicators of the attention	BAL- (M ± SD)	BAL+ (M ± SD)	d	t-test (p-value)
Bal (SS)	6.1 ± 0.8	11.4 ± 2.4	**2.10[a]**	**< 0.001**	**QAP (SS)**	113.1 ± 12.3	113.7 ± 12.6	0.05	0.457
Bal1 (SS)	7.5 ± 3.7	12.0 ± 1.7	**2.14[a]**	**< 0.001**	**TAP (SS)**	108.0 ± 17.0	113.2 ± 13.3	0.37	0.231
Bal2 (SS)	2.8 ± 1.2	9.9 ± 3.0	**2.67[a]**	**< 0.001**	**PCA (SS)**	96.6 ± 23.8	106.9 ± 16.5	**0.58[b]**	0.083
Bal3 (SS)	10.3 ± 2.8	11.0 ± 1.4	0.34	0.155					

Legend: Bal - total performance in the balance tests; Bal1 - performance in the static balance test Two-board balance, Bal2, Bal3 - performances in the dynamic balance test Walking toe-to-heel backwards and test Zig-zag hopping, resp.; QAP – quantity of attention performance; TAP – total attention performance; PCA – performance of concentration of attention; SS – standard score; BAL- and BAL+ - the group with and without the deficit balance, resp.; d - Cohen´s effect size coefficient; [a] large effect size, [b] moderate effect size.

Conclusions

The groups significantly different in the total balance performance (Bal) differed significantly both in static (Bal1) and dynamic (Bal2) balance abilities. Although no significant correlations ($p>0.05$) between the balance and attention indicators were found, the performance in the selected aspects of attention were higher in the BAL+ group in comparison to the BAL- group. However, concentration performance only showed to be significantly higher in the BAL+ group than in the BAL- group. The study suggested that under condition of a single both static and dynamic balance task, postural stabilization can be affected by a rate of concentration of attention rather than by the subject´s attention capacity.

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EIGHT WEEKS OF INSTABILITY RESISTANCE TRAINING EFFECTS ON MUSCULAR POWER OUTPUTS

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Introduction
Previous studies have suggested that resistance training exercise under unstable conditions decreases the isometric force output, yet little is known about its influence on muscular outputs during dynamic movement. It is purported that greater instability of the human-surface interface will stress the neuromuscular system to a greater extent than traditional resistance training methods using more stable benches and floors. The advantage of an unstable training environment would be based on the importance of neuromuscular adaptations with increases in muscular outputs. The objective of this study was to determine differences in muscular outputs, such as power, force and velocity, after stable and unstable resistance training. It was hypothesized that instability resistance training would provide significantly greater training gains in muscular outputs.
Methods
Fifty students of Faculty of Sport and Physical Education were randomly divided into equal groups. First group (unstable) subjects' trained 2 days per week under unstable conditions for 8 weeks, while second group (stable) subjects' trained under stable conditions in the same regime. All of subjects were recreationally active but were not participating in any particular sports or activities on a consistent basis, or in a resistance training program in the last year. Prior to the study, subjects were exposed to a two familiarization sessions. All exercises were performed with previously established 50% of one-repetition maximum (1RM). Stable condition was given by a flat bench. The unstable condition was given by a Swiss ball with a diameter of 65 cm placed to support only the upper back, not the cervical area or head and with the feet placed on the floor. Barbell squats on stable surface or unstable BOSU ball (Fitness Quest, Canton, OH, USA) were performed from full extension to a knee angle of 90° while holding a barbell on the back. Power output for each repetition was measured by Fitrodyne dynamometer (Fitronic, Slovakia) according to protocol suggested.
Results
There were no significant effects found for training groups in muscular outputs during bench press. However, there was a 26% increase in power associated with instability training compared with 12% increase in stability training group. Also velocity of maneuver was increased for 21% in unstable group subjects compare with 8% in stable group. Muscular outputs during squat maneuvers were significantly increased ($p<0.05$) after 8 weeks unstable resistance training. Post training increase for unstable group were 46% for power and 39% for velocity during squat maneuver compare to 10% and 8% in stable group, respectively.
Conclusions
This study used 50% of 1RM for the training of previous resistance training inexperienced subjects because the use of a heavy weight in such an unstable condition may be very dangerous and may lead to anxiety about falling, which would compromise the validity of the measurement. However, obtained results have demonstrated that instability resistance training may be considered as effective as traditional stable resistance training for inexperienced resistance trainers. It appears that instability resistance training, which reportedly uses lower forces, can increase muscular outputs in previously untrained young individuals similar to training with more stable machines employing heavier loads.

Keywords: *instability, power, resistance training, bench press, squat*

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CHARACTERIZATION OF PARKINSON'S DISEASE SUBTYPES USING AN ACCELEROMETER-BASED POSTURAL ANALYSIS: A CLUSTERING APPROACH

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Introduction

The different motor-symptoms subtypes of Parkinson's disease (PD) often progress and respond to interventions in diverse ways. It is therefore important to be able to accurately identify and monitor subjects based on this classification and to follow their motor symptoms over time. This study has two aims: 1) to test whether data analyses, based on a simple instrumented postural test, may give information on subtypes comparable with the classification based on the standard UPDRS clinical test; 2) to evaluate if this tool can provide information that cannot be obtained by the clinical evaluation alone.

Methods

Thirty-five subjects with PD (Hoehn and Yahr scale: 2.4±0.6) were tested OFF medication. 18 subjects were clinically classified into the postural instability and gait difficulty (PIGD) subtype, 14 as Tremor Dominant (TD) and 3 were not classifiable (NC) [1]. Postural sway in 4 conditions (feet together/semi-tandem; eyes open/closed) was recorded during 2 consecutive 30 s trials, using a tri-axial accelerometer (McRoberts Hybrid, 100 Hz) on the lower back. Twenty measures were extracted from each trial: some from the raw signals to quantify tremor, the others after a customized low-pass filter to quantify only postural sway [2, 3]. We then applied an unsupervised classification technique (k-means) to look for homogeneous groups of PD patients in 2D plane of uncorrelated postural measures. We then selected the best clustering result [4] and compared it with the clinical classification (TD and PIGD subjects).

Results

The optimal unsupervised clustering result was found in the semi-tandem eyes-open condition considering (Fig. 1): the % of Power in High Frequency components in anterior-posterior (AP) direction (related to tremor in AP) and the Sway Path in the medio-lateral (ML) direction. This clustering result includes 3 clusters: A) Cluster with High AP Tremor; B) Cluster with Low AP Tremor and Low ML Sway; C) Cluster with Low AP Tremor, High ML Sway. Two of the three obtained clusters are very similar to the clinical subtypes: cluster A) ≈ TD; cluster B) ≈ PIGD. Cluster C) has no direct relation with clinical classification.

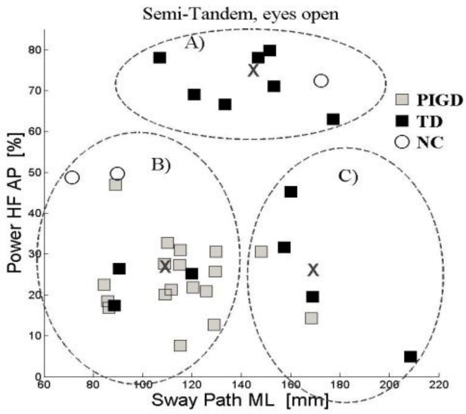

Figure 1. Unsupervised clustering results

Conclusions

Clinically-classified TD subjects were described only by high tremor related quantitative measure. This variable seems to be specific but not enough sensitive for the TD subjects (specificity: 100%, sensitivity: 50%), since some are classified in other clusters. This could be considered as an added value to the clinical classification: even if these subjects are considered to be TD, their tremor is not detected during postural tests. The PIGD group is well described by cluster low ML sway and low AP tremor (specificity: 79%, sensitivity: 89%). A possible explanation is that rigidity may lead to low ML sway. The present study suggests that accelerometer-derived measures may augment the clinical evaluation and help to classify, monitor and quantify different PD types and their evolution over time, such as the response to therapeutic interventions.

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METHODOLOGIES TO COMBINE OBJECTIVE MEASURES OF MOBILITY

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Introduction

We have recently introduced an objective, short and easy to use clinical test to assess several important aspects of mobility including postural sway, anticipatory postural adjustments (APA), gait and turning called ISAW [1]. While obtaining objective, reliable and sensitive outcome measures is desirable, the large number of outcomes makes interpretation of the results and clinical decision making difficult. The objective of this study was to investigate different methods to combine these objective measures into objective scores.

Methods

Sixty eight subjects with moderate Parkinson's disease (PD) were tested (ON state). The average age was 66.6 ± 6.3 years. The average UPDRS motor score was 33.3 ± 10.3. Each subject performed 3 trials of ISAW. The ISAW analysis algorithms automatically estimated a large number of objective measures related to postural sway (65), APA (10), gait (57) and turning (7). In a pre-preprocessing step, only those measures that had at least moderate test-retest reliability (ICC > 0.7) across the 3 trials were selected. 24 measures met this criterion. Measures from the 3 major components of ISAW were present. Data from 75% of the subjects was used for training and the rest for validation. Postural Instability and Gait Deficiency subscore of motor UPDRS (PIGD) was selected as the gold standard. Three different model building strategies were evaluated: 1) Linear combination of the measures (LM) - we use AIC for model selection and evaluated all possible subsets of the measures up to 5 components; 2) Random-Forest - we used an ensemble of 1000 decision trees to build a random forest (RF); 3) Factor analysis (FA) - we used exploratory factor analysis and selected 4 latent variables as the underlying factors explaining the data. These factors were linearly combined to estimate PIGD.

Results

FA method found 4 factors mainly related to gait speed, range of motion of the upper limbs, stride-length and balance. Table 1 shows the correlation between the estimated and real score for each model building method. Performance of all methods on the training dataset was good while RF method showed exceptional results. On the validation dataset, however, performance was poor with RF method showing the best results and LM model showing the worst.

Discussion

Results suggest that it is rather difficult to build a predictive model to estimate a semi-subjective clinical score using objective measures. RF method showed the best predictive results on the validation dataset, yet the accuracy of its predictions remained low. RF is hard to interpret and behaves mostly like a black box, making it a poor choice for clinical decision making. The results suggest that clinical scores such as PIGD might be too noisy to be used reliably as a gold standard to build objective scales. Still, with a much larger sample size, it might be possible to improve the predictive models. While FA method did not show results as good as the RF method, it could summarize the large set of the objective measures into few, easy to understand factors. The method to estimate these factors is purely objective thus we believe at this stage FA method might be more practical and more useful than other methods.

Table 1 Correlations between UPDRS PIGD subscore and its objective estimates.

Method	Training set	Validation set
Linear model	0.75	0.08
Random Forest	0.97	0.28
Factor Analysis	0.70	0.14

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PROCESSING TIME OF VISUAL AND TACTILE STABILIZING INFLOW DURING STANCE

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Introduction

Vision and touch help stabilize our standing body. Little information exists on the time-interval necessary for the brain to process the sensory inflow (or its removal), and to exploit the new sensory signal (or to counteract its removal) in the control of bipedal stance [1]. Further, does expectation of the stabilizing sensory inflow (or its removal) modify this time-interval?

Methods

Ten subjects (mean age 25 yrs, 5 males, 5 females) stood in tandem position. They wore LCD goggles that allowed or removed vision depending on a TTL (Transistor-Transistor Logic) signal. Alternatively, subjects stood eyes-closed with the index finger in a position apt to accept a rising solid surface with an embedded strain gauge. In different sessions, sensory-change conditions were also deliberately produced by opening (or closing) the eyes or by touching the surface (or lifting the finger from it). Eyelid movement and finger force (about 1 N) were recorded. In separate trials, subjects were invited to rapidly contract their postural muscles in a reaction-time mode on perceiving the sensory change. We simultaneously recorded the centre of foot pressure by means of a force platform (Kistler, CH) and the EMG (FreeEMG, BTS, I) of soleus, tibialis anterior and peroneus muscle, bilaterally, and of the extensor indicis of the touching finger.

Results

Body sway and postural muscle activity increased on closing the goggles and on withdrawing the haptic surface; across the subjects, the time-interval to onset of increase in leg muscle EMG and sway was around 1-2 s under the both conditions. This time-interval was slightly but significantly shorter than that to the decrease in EMG and sway occurring on addition of vision or touch. The delay to changes in EMG and sway on arrival of haptic was generally longer than on arrival of visual information. Only minor anticipations of the onset of the relevant change in postural control mode from the change in sensory condition were found when vision was obtained or removed by voluntarily opening or closing the eyes, or haptic sense modified by voluntarily lowering or lifting the finger from the surface. The automatic changes in muscle activity and body sway were adaptive from the beginning of the sensory change and exponentially tended to the pattern characteristic for the given sensory set. The latency of voluntary, reaction-time responses of the postural muscles to changes in sensory conditions were around 200 ms (for both touch and vision), i.e. much shorter than the automatic postural adjustments. In some cases, startle responses at around 100 ms latency from the sensory change preceded the changes in EMG and sway.

Conclusions

The time-interval to modify the 'postural set' in response to sensory transitions is much longer than a spinal reflex or a startle response, and even longer than visual or tactile reaction-time responses. Therefore, the changes in control require a finite amount of time from the sensory shift, connected with the process of central integration of visual or haptic information in the postural control mode. This time-interval is shorter when vision or touch are removed than added, likely indicating a heavier computational cost for handling the entry than the exit of the new information. These intervals strictly depend on the addition or removal of the sensory information and are only minimally reduced by knowledge of the impending sensory state, as when subjects voluntarily seek the new sensory condition. The time-interval elapsing between occurrence of a change in haptic or visual set to adapted change in motor set includes the time to: a) integrate the newly available sensory inputs, b) adjust the calibration of the motor activity in time and amplitude to reach the best motor control with the new sensory set. This protocol can be exploited for investigating early disorders of sensori-motor organization.

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DIFFERENTIAL ROLES OF LEG MUSCLES DURING TANDEM STANCE

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Introduction

When standing with the feet in tandem position, postural muscle activity is larger than under quiet stance with feet parallel. Further, the increase in muscle activity becomes much larger when vision is withdrawn. These patterns of activity accompany increases in oscillations of the centre of foot pressure (CoP). While a lot is known about postural muscle activity during standing with feet parallel, even under critical postural conditions [1], little information exists as to the distribution of activity among various leg muscles and between legs under tandem conditions [2]. Moreover, how destabilization by vision deprivation recruits these muscles is still unidentified.

Methods

Ten subjects (mean age 25 yrs, 5 males, 5 females) stood in tandem position. They wore LCD goggles that allowed or removed vision depending on a TTL (Transistor-Transistor Logic) signal. We simultaneously recorded the position and displacement of the body's centre of foot pressure by means of a force platform (Kistler, CH) and the EMG (FreeEMG, BTS, I) of soleus, tibialis anterior and peroneus muscle, bilaterally, during from 50 to 100 10s-standing trials, both with and without vision. No notable EMG cross-talk between muscles was detected. For each muscle, EMG activity was normalized to that recorded during maximal voluntary contraction. For each subject and vision condition, the average level of the rectified EMGs during each 10s-period entered the analysis. The amplitude of the medio-lateral oscillation was the average of the rectified and filtered traces of the CoP displacement.

Results

Under the tandem conditions, the CoP was normally lying at about the forepart of the foot of the rear leg. Body sway and postural muscle EMG activity increased in the absence of vision. For each muscle of both legs, the average activity was plotted against the average medio-lateral CoP oscillations, separately for vision and no-vision trials. It turned out that the increase in soleus activity was not correlated to the increase in oscillation, both within and across visual conditions, and regardless of the leg. Conversely, the tibialis and the peroneus activity definitely increased when oscillations increased. This relation was much steeper for the rear than the front leg. For the tibialis of the rear leg, EMG further increased no-vision. An increase in the variance of the EMG profile always accompanied the increase in mean EMG level; but this relation was steeper for tibialis than peroneus than soleus and for no-vision. The difference between the EMG levels of the homonymous muscles of both legs was related to the antero-posterior position of the CoP for soleus and tibialis, not for peroneus. When, across subjects and trials, CoP was more anterior, the differences in EMG activity between legs vanished.

Conclusions

When standing under the tandem condition, the rear leg is mainly involved in the control of equilibrium. While the soleus plays a supporting role, the peronei appear to control medio-lateral oscillations. The tibialis seems to mostly control the increase in oscillation connected to vision withdrawal. These data give insight into the complexity and the functional plasticity of the neural mechanism appropriately controlling the recruitment of postural muscle during tandem stance, a condition often used to highlight balance disorders.

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STAR EXCURSION BALANCE TEST AS A HELPFUL TOOL FOR CLINICAL PRACTICE

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Introduction
Deteriorating balance control in elderly or diseased patients, or patients after injury or surgery, leads to increase risk of falls and posture impairments. To be aware of this risk and to be able to monitor the improvements or worsening of balance control, dynamic balance tests are used in clinical practice. One of them is Star Excursion Balance test, originally used to monitor the athletes with chronic ankle instability after injury [1].

Methods
The group of 14 patients, 3 men and 11 women, 40-73 years old (average age 55 years), with functional disorders of motion apparatus were assessed before and after the 2-week spa therapy focused on balance training, proprioceptive stimuli and adjustment of muscle disequilibrium. The set of tests included tests for reactive postural responses, anticipatory postural reactions, functional reach test with upper extremities and Star Excursion Balance test. Collected data before and after the treatment was statistically evaluated with the two tailed paired Student t - test.

Results
Scores in the tests of reactive postural responses and anticipatory postural reactions showed statistically highly significant difference before and after the treatment ($p \leq 0.0001$). The same high statistical difference ($p \leq 0.0001$) was found in functional reach test and also in Star Excursion Balance test.

Conclusions
Positive effects of the tailored therapy on the balance control mechanisms in patients with functional disorders of motion apparatus were observed. Star Excursion Balance test seems to be reliable and valid test for balance control monitoring. Its simplicity and low material demandingness, as well as its objectivity make it very applicable in everyday clinical practice.

Keywords: *balance, balance control, Star Excursion Balance test, physiotherapy*

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GAIT DEVIATION DURING COMBINED VISUAL-VESTIBULAR STIMULATION IN ROLL

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Introduction
Human gait involves multimodal processes. Proprioceptive, visual and vestibular inputs modify gait. Galvanic vestibular stimulation (GVS) induces body sway and gait deviation to the anodal side of stimulation [1]. Visual motion stimulation (VMS) in roll also induces gait deviation in the direction of pattern motion [2, 3, 4]. Functional imaging has shown that vestibular input causes deactivation in the visual system and vice versa. Patients with bilateral vestibular failure (BVP) do not show visual deactivation. This was postulated as a permanent shift to the visual system [5, 6]. In the present study we examined the interaction of GVS and VMS and its influence on gait performance in healthy subjects.
Methods
Twelve healthy subjects (5 females, aged 26-38 years, mean 29.9±4.1, one left hander) were examined in a gym (10x6m). GVS was applied at mastoid processus (direct current, 0.9-2.5mA) with left and right anodal stimulation. VMS was applied by a whole visual field random dot pattern rotated constantly in roll at +/-15 °/s. Gait deviation was measured by a stereo camera system detecting a light-emitting infrared diode fixed at the back of the subject. All subjects performed three runs for each of the following conditions: without any stimulus (=baseline), GVS and VMS convergent, GVS and VMS divergent. For analysis, angles of deviation were calculated. Eye movements were detected by video-oculography (VOG).
Results
In the convergent condition, gait deviation differed significantly from baseline ($p<0.0001$; post hoc: right: $p<0.05$; left: $p<0.05$). There was no significant difference between baseline in the divergent condition ($p=0.076$). Gait deviation was larger for convergent compared to divergent stimulation (right: $p=0.019$; left: $p=0.012$). More torsional eye movements were observed in convergent condition. Differences of angles of gait deviation between right and left stimulation were larger for the convergent condition ($p=0.019$).
Conclusions
Visual and vestibular stimulation during gait influence each other. If inputs are convergent, there is a summation of effects in healthy subjects. If inputs are divergent, effects on gait are diminished. This superposition of GVS and VMS during locomotion indicates that GVS, just like VMS, constitutes an angular motion stimulation in roll, as previously hypothesized [7] and shown [8] for eye movements. This paradigm will be helpful to investigate visual-vestibular interaction in patients with sensory deficits.

Keywords: *galvanic vestibular stimulation, visual motion stimulation, dual task, gait*

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THE INITIATION OF LOCOMOTOR-LIKE MOVEMENTS BY MUSCLE VIBRATION AND PASSIVE LIMB MANIPULATION IN HUMANS

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Introduction
The vibration (V) applied to an unloaded leg elicits involuntary step-like movements; this suggests that tonic stimulation of Ia afferents can activate spinal CPG in healthy humans [1, 2]. Earlier, initiation of such air-stepping took a few 2-4 h sessions of V with an about 50% success rate, which limits both research and clinical usage of V. We explored the effects of combined V and rhythmic passive arm movements (PAM) as the means to induce locomotor-like involuntary movements.
Methods
Eighteen healthy naive volunteers participated in this study. The subject lied on the left side with the right leg and arm suspended. Arm and leg kinematics were recorded with a ProReflex system at 240 Hz. During pre- and post-stimulation (PreStim, PostStim) a Hip Release Test (HR) was used - the leg extended backward to cranio-caudal line of the body was passively released. HR was performed separately and in combinations with 80 Hz Achilles tendon V, rhythmic passive movement in the shoulder and elbow joints (PAM), and V+PAM, with 3 trails of each test. Further, V+PAM was continuously applied and HR was repeated. If 'stepping' was not evoked within 40 min the subject was qualified as a non-Responder. In Responders , after a stable locomotor reaction to combined V+PAM was reached, we randomly switched off one or both factors (V and PAM).
Results
PAM+V+HR induced 'stepping' in 9 subjects (50%) within 17-38 min of the first session, whereas the same factors applied separately or in pairs were not effective. The comparison of responses to HR between Responders and non-Responders showed significantly higher amplitude in knee joint excursion, longer lasting response and lower decrement of motion in Responders (Fig.1) at all testing (PreStim, Stim, PostStim).
The amplitude of stimulation-induced movements was within 20-60° in the hip and 5-80° in the knee joints and the frequency was about 0.4 Hz. The rhythmic leg movements lasted all the time of PAM and continued about 3-5 min after PAM stopped. Switching V off led to a decrease of HipDecr up to 60% as compare to pre-stop level. The stop of PAM and V+PAM multipled the HipDecr by 3 to 6. ANOVA on the HipDecr produced by HR test showed significant effect on PAM ($p<0.001$) and no effect on V.
Conclusions
Combined (V+PAM+HR) stimulation facilitates initiation of locomotor-like motion but it does not increase the proportion of responsive subjects. Pre-Stim parameters tested with HR could be predictors of locomotor response to combined stimulation. To initiate 'stepping' the combination of tonic (V) and phasic (PAM) stimulation is effective; to keep continuing stepping the phasic afferent stimulation by PAM, likely via propriospinal pathways is more important.

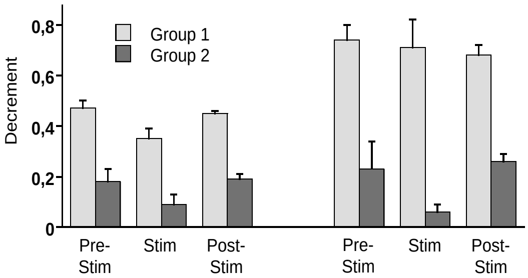

Figure 1. Decrement of the hip joint motion (HipDecr) in groups of non-Responders (Group 1, n=9) and Responders (Group 2, n=9) subjects (means across subjects, with SE bars). Note the group difference before stimulation (Pre-Stim) as well as during and Post-Stim.

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AGE-RELATED DIFFERENCES IN GAZE BEHAVIOUR DURING VIRTUAL WALKING

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Introduction
Laboratory studies comparing the gaze behaviour of older and younger adults during walking demonstrate that older adults with a high risk of falling adopt seemingly maladaptive visual sampling behaviour which results in reduced stepping accuracy and increased risk of falling [1, 2]. However, these studies have limited ecological validity and therefore the observed gaze patterns may not be representative of real world behaviour. The aims of the present studies were: 1) to quantitatively compare gaze behaviour obtained during real world walking to that collected during scene viewing and 2) to identify any age-related differences in gaze behaviour during scene viewing, which might add to our understanding of the mechanisms underlying increased incidences of falls with age.
Methods
Experiment 1: An ASL 500 mobile eye tracking system was used to record the gaze behaviour of 10 young adults (mean age 24.7 yrs, 4 females, 6 males) under two experimental conditions:
1) The participant walked around a predefined route in our academic department representing a real-world environment (a separate image of the route was recorded for use in condition 2),
2) the participant watched the scene recorded in the first condition on a large screen.

The extent of similarities between spatiotemporal aspects of gaze behaviour measured under the two conditions was assessed using Pearson's Product Moment correlation.
Experiment 2: Nine younger adults (mean age 24.3 yrs, 6 female, 3 males), eight low risk older adults (mean age 68.9 yrs, 6 female, 2 males) and six high risk older adults (mean age 74.2 yrs, 5 females, 1 male) watched scenes from a first person perspective of various everyday real-world walking scenes, e.g. walking down a high street, walking along a canal, etc. while their gaze patterns were recorded. The results were then compared to ascertain if there were measureable differences between the percentage of time participants visually sampled different characteristics of the scenes between groups.
Results
The results from Experiment 1 showed significant correlations between the temporospatial characteristics of gaze behaviour for the length of time that environmental features were fixated ($r=0.96$, $n=10$, $p<.001$) and the number of times each of the environmental features were fixated ($r=0.97$, $n=10$, $p<.0001$). Preliminary analysis from Experiment 2 showed that there was a significant main effect of participant group on the percentage of time participants fixated aspects of the travel path ($F_{(1,2)}=3.5$, $p<0.05$). Pair-wise comparisons revealed that, on average, the high risk older adults fixated the travel path for a significantly longer time (mean percentage time=62%, 95% confidence limits=37.35 & 86.26) than the low risk older adult (mean percentage time=43%, 95% confidence limits=37.87 & 48.3) and the younger adults (mean percentage time=45%, 95% confidence limits=35.51 & 53.41).
Conclusions
The findings from Experiment 1 provide encouraging evidence that a virtual environment can be used to investigate real-world gaze behaviour. The preliminary analysis from Experiment 2 supports the hypothesis that a scene viewing paradigm can identify measurable differences between gaze behaviour of high and low risk older adults which are consistent with those measurable during real walking tasks [1, 2, 3]. In combination these findings suggest that measuring gaze during scene viewing paradigms may be useful for identifying and understanding the mechanisms underlying suboptimal visual behaviour in frail individuals that contribute to their increased risk of falling.

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EFFECTS OF ACUTE EXPOSURE TO A STRESSOR ON UPPER TRAPEZIUS MUSCLE ACTIVITY

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Introduction

Interactions between stress and the motor system have been reported for healthy [1] and patient [2, 3] populations, however the physiologic mechanisms underlying this relation are not known. Muscles with a prominent postural role, such as the upper trapezius muscle, are among the most responsive to stress [4], and provide an excellent model for investigating the link between stress and the motor system. We conducted a series of studies to investigate physiological mechanisms underlying the effects of stress on the upper trapezius muscle, and the high level of inter-intervidiual variability [5] in this relation.

Methods

We used intramuscular electromyography to examine the behaviour of upper trapezius motor neurons during active contraction (Study 1; 21 healthy women, age 23-55 yr) and periods of intended muscle rest (Study 2; 15 healthy women, age 23-55 yr) during exposure to low and high levels of psychosocial stressors. We used transcranial magnetic stimulation (TMS) to examine the responsiveness of intracortical pathways projecting onto the corticospinal pathway in 17 individuals with chronic neck pain (Study 3; 10 women, 7 men; age 24-58 yr), during exposure to low and high levels of psychosocial stressors. In all studies stress exposure was manipulated using a mental math task combined with social evaluative threat.

Results

Exposure to the high stress condition increased perceived anxiety, heart rate and blood pressure in all studies ($P \leq 0.002$). Study 1: Discharge behaviours (including motor unit recruitment, discharge rate and variability, and double discharges) and the input-output processing properties of motor neurons recorded during active contraction were similar across low and high stress conditions ($P \geq 0.121$). Study 2: The amount of motor unit activity present during periods of instructed rest increased under high stress conditions (P=0.021). The frequency content of this motor unit activity at respiratory (0-0.5 Hz) and beta (16-32 Hz) band widths was similar during low and high stress conditions (P=0.391 and P=0.089 respectively). Study 3: The corticospinal tract was more responsive under high stress condition, as evidenced by a reduced motor threshold ($P<0.001$) and increased recruitment curve slope (P=0.001). The responsiveness of intracortical inhibitory (P=0.226) and facilitatory (P=0.712) pathways were unchanged across test conditions. However, the responsiveness of inhibitory pathways changed in opposite directions for individuals who successfully maintained a quiescent muscle throughout the high stress condition (N=7; exhibited increased inhibition) and those who exhibited an increase in muscle activity (N=6; exhibited no increase in inhibition; P=0.024).

Conclusions

We found no evidence to suggest that changes in the intrinsic properties of trapezius motor neurons contribute to the motor response to stress (Study 1). Furthermore, although trapezius motor neurons received inputs at respiratory and beta frequencies, the motor response to stress was not associated with changes in these inputs (Study 2). Although the physiologic mechanism the stress responsiveness of the upper trapezius muscle is not clear, differential modulation of intracortical inhibition appears to underlie inter-individual variability in whether or not this increased responsiveness is manifest as elevated muscle activity (Study 3). We speculate that increased intracortical inhibition is required to compensate for increased excitability elsewhere in the corticospinal pathway during acute exposure to stressors, and that failure of some individuals to appropriately modulate this inhibition can lead to elevated muscle activity.

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THE INFLUENCE OF ACTIVE PRONATION AND SUPINATION ON THE MOVEMENT OF THE LOWER LIMBS AND PELVIS DURING GAIT

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Introduction

The foot plays an important role in walking. Some studies assess the biomechanical effects of wearing wedged insoles on subtalar and knee joints during normal walking [1]. But the change in the position of the foot can also affect the more proximal segments of the body. The aim of this study was to evaluate the influence of active pronation and supination on the movement of the lower limbs and pelvis during gait.

Methods

Thirty male subjects (age 23.8±2.48 years, height 182.7±5.9 cm, weight 79.0±8.2 kg) participated in this study. 3D kinematic data were collected by Vicon MX system (7 infrared cameras, Vicon Motion Systems, Oxford, UK). Sixteen reflective markers were used to define a model of the pelvis and lower limbs. Normal gait, gait with active foot pronation and gait with active foot supination were observed. During gait, the angular motion of the hip, knee, and ankle joints and of the pelvis were evaluated in three planes. Data was processed by the Vicon Nexus and Vicon Polygon programme. Statistical processing was performed by the Statistica programme (version 8.0, Stat-Soft, Inc., Tulsa, Oklahoma, USA) using sign test.

Results

Between gait with active pronation and normal gait we found greater flexion (Fig. 1), valgosity and internal rotation in the knee joint. These variables were smaller than in normal gait during gait with active supination. For hip and pelvis variables we found similar tendencies for both active pronation and active supination. Gait cycles were characterized by the reduction in the range of movement in the hip joint in all three planes and the reduction in pelvic movement in frontal plane (Fig. 2).

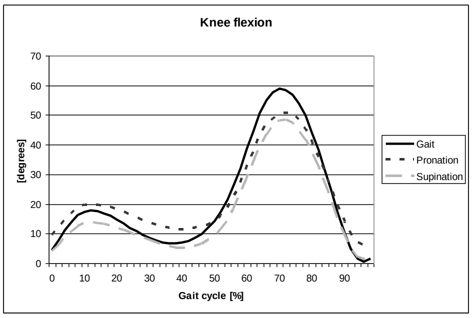

Figure 1. Knee flexion

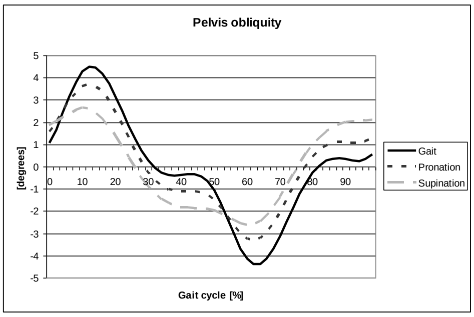

Figure 2. Pelvic obliquity

Conclusions

Gait with active foot pronation and gait with active supination affect the movement of the whole lower limb and pelvis.

Keywords: *gait, kinematic analysis, foot, pronation supination*

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HEAD EXTENSION EFFECT ON POSTURAL RESPONSES TO GALVANIC VESTIBULAR STIMULATION

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Introduction
In patient with peripheral vestibular dysfunction, the head extension showed stabilizing effect on their upright posture. Healthy subjects demonstrate increased standing postural instability with their head extended [1, 2]. It was suggested that a displacement of utricular otolith organs beyond their working range by head extension lead to vestibular function disruption. To examine this hypothesis we compared galvanic vestibular stimulation effect on upright posture between direct head position and head extension.

Methods
Nine healthy subjects (20 - 42 yrs) took part in the study. The unilateral galvanic vestibular stimulation (GVS; sinusoidal current F 0.3 Hz, amplitude 0.6 mA) right and left was used to induce postural responses during quiet stance. The subjects stood in following situations: eyes opened, eyes closed, eyes closed with head extension, GVS with eyes closed and direct head position, GVS with eyes closed and head extension. The postural responses were recorded by force platform for 50 s. Galvanic vestibular stimulation induces body sways mainly in lateral direction. In regards to that we compared sway amplitudes in lateral direction between conditions. The statistical analysis was done by paired t-test.

Results
In stance condition with eyes opened and closed, all subjects showed no balance impairment. There was no statistical difference between lateral sway amplitudes induced galvanic vestibular stimulation on right or left side. In seven subjects, lateral sway amplitude was decreased during standing with head extension compared to stance with direct head position without regards to the side of stimulation. In two subjects, we observed larger lateral sway amplitude in direct head position in galvanic stimulation on one side. In the same subjects the galvanic stimulation of the opposite side showed decreased lateral sway amplitude in stance with head extension. For statistical analysis we put data obtained by stimulation right and left side together. Comparing lateral sway amplitudes between galvanic vestibular stimulation direct head position and head extension showed statistically significantly ($p<0.01$) decreased lateral sway amplitude in stance with head extension.

Conclusions
Our results showed that the effect of galvanic vestibular stimulation was decreased, when subjects were standing with head extension. This observation is congruent with the hypothesis, that vestibular output is disrupt when the vestibular apparatus is out of ideal space coordinates. Also, the observed stabilizing posture effect of head extension in patients with peripheral vestibular disorders might be explained by decreased vestibular role in the posture control when the head is extended. Similarly, Norre [2] observed in some patients improving posture stability with head extension.

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STATIC BALANCE AND VISUAL FEEDBACK CONTROL OF BODY AND ELDERLY INDIVIDUALS

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Introduction
The study compares postural stability under various conditions and accuracy of visual feedback control of COP movement in antero-posterior and medio-lateral direction during a COM tracking task.
Methods
Subjects (26 physical education students of age 21.9 ± 1.4 yrs, height 177 ± 5.4 cm, weight 74.3 ± 8.6 kg, and 26 elderly of age 58.4 ± 4.3 yrs, height 169.3 ± 6.8 cm, weight 71.8 ± 9.2 kg) were provided by feedback on COM displacement on a computer screen while standing on dynamometric platform. Their task was to trace, by shifting COM, a curve flowing either in vertical or horizontal direction. The deviation of instant COP position from the curve was recorded at 100 Hz by means of the system FiTRO Sway Check. The same system was used to register COP velocity during quiet standing under various conditions, such as bipedal stance with eyes open, bipedal stance with eyes closed, bipedal stance on foam with eyes open, and bipedal stance on foam with eyes closed.
Results
Results showed that mean COP distance from the curve did not differ significantly in elderly and young individuals, in both vertical (13.5 ± 3.3 mm and 13.1 ± 2.4 mm, respectively) and horizontal direction (14.7 ± 3.2 mm and 14.5 ± 2.7 mm, respectively). Similarly, there were no significant differences in COP velocity in these groups neither on stable platform with eyes open (10.4 ± 1.9 mm/s and 10.4 ± 1.8 mm/s, respectively) and eyes closed (14.8 ± 3.9 mm/s and 13.0 ± 3.0 mm/s, respectively) nor on foam surface with eyes open (15.7 ± 4.3 mm/s and 14.7 ± 2.8 mm/s, respectively). However, the COP velocity was significantly ($p \leq 0.05$) higher in elderly than young individuals during standing on foam with eyes closed (43.0 ± 13.8 mm/s and 38.9 ± 8.7 mm/s, respectively).
Conclusions
It may be concluded that only bipedal stance on foam with eyes closed discriminate postural stability in young and elderly individuals. Novel task-oriented balance tests are not sensitive enough to differentiate between groups with different level of balance capabilities.

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THE CONTROL OF POSTURE INTERFERES WITH THE LEARNING OF A MIRROR TRACING TASK IN OLDER PEOPLE

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Introduction

Mirror tracing leads to a conflict between the visual inputs and proprioceptive signals [1, 2]. When first confronted with the task, healthy individuals have difficulties when changing directions and particularly when tracing oblique lines. Following several practice trials, however, subjects learn to resolve this conflict resulting in an improved performance (less time to complete the task and the tracings are less erratic). Bernier et al. [2] showed that the initial exposure to a mirror-reversed condition is accompanied by substantial suppression of somatosensory signals occurring in the primary somatosensory cortex (S1). This sensory gating is gradually alleviated as performance increases with adaptation, returning to baseline levels after ~30 min of exposure. The authors suggested that the suppression of somatosensory information may functionally serve to reduce the sensory conflict until the mapping from hand to visual space is updated. If learning to trace mirror-reversed patterns requires attenuation of somatosensory inputs, performing this task upright implies that the brain needs to attenuate signals from the upper arm but not those related to body sway to ascertain proper balance control. The ability of the brain to process afferent signals from the hand and from posture independently may be impaired with aging. When transferring from an upright to a seated condition, an increased in the tracing performance would suggest older people have a difficulty in processing sensory inputs from the hand and posture independently.

Methods

A group of 11 young individuals (7 male and 4 female; age: 22.5 ± 2.6 yrs) and 10 older healthy individuals (5 male and 5 female; age: 68.6 ± 2.4 yrs) participated in this study. They drew a six-pointed star template with an ink-less stylus in a mirror-reversed view (mirror condition) either in a standing or a seated posture. They also performed the task with direct vision while standing (normal condition). The experiment was run over 3 consecutive days. On each day, subjects first performed the task while standing. Instructions were both to minimise errors and to go as fast as possible. The first 12 trials were performed in the mirror-reversed condition and the last 3 trials in the normal condition. On the last day, a 5-min rest period was given after the 15 trials. Then, all subjects transferred to the seated condition where they performed 12 additional mirror-reversed trials.

Results

When standing, both groups improved their tracing performance within each day and across days (shorter duration to trace the star pattern, fewer number of changes in direction, smaller total hand displacement and a smaller disfluency index). Both groups also retained the new mapping from hand to visual space as the time needed to complete the pattern for the first trial decreased systematically between subsequent days. For both groups, the performance did not differ between the last 6 trials of the third day of practice suggesting both groups had achieved a plateau in their tracing performance. The older participants, however, were still slower than the younger subjects and showed more changes in direction. It is noteworthy that this observation did not result just from a general slowness of older participants. Indeed, in the normal vision condition, older participants, albeit they were still slower than younger subjects, improved considerably their tracing performance (on average for the older subjects, 66.0 s vs. 21.9 s for the last three trials of the mirror-reversed and normal vision condition, respectively; 18.9 s vs.10.9 s for the younger participants). After three days of practice, all subjects transferred to a mirror-inverted seated condition. Tracing data for Day 3 (mirror-inverted condition; upright and seated conditions) were submitted to Group (Young and Older participants) by Posture (Upright and Seated) by Block (4 blocks of 3 trials) ANOVAs with repeated measures on the last two factors. A main effect of Group and a significant interaction of Group by Posture were observed for all tracing variables ($Ps < 0.05$). Figure 1 illustrates the interaction of Group by Posture for all four dependent variables. For young subjects, transferring to the seated condition did not modify the tracing performance. This was confirmed for all four variables through specific comparison of means (Tukey HSD) between the upright and seated condition ($Ps > 0.05$). In contrast, when transferring from the upright to the seated posture, older people showed a shorter time to complete the pattern, fewer number of direction changes, a lower disfluency index and a shorter pen total displacement ($Ps < 0.05$).

Conclusions

After 3 days of practice, for older people, the standing posture still interfered with the tracing performance. Both groups learned the task but the young adults were much better than older people for all tracing variables. The most important result of this study is the improved tracing performance of older people when they transferred from the standing to a seated posture. This indicates that older people were more affected by the regulation of their posture then young adults. This may suggest that the parallel processing of somatosensory inputs or filtering arm somatosensory inputs to improve tracing performance while standing is altered with aging. The coordination between balance control and upper arm movements might be a bigger challenge for older people [3].

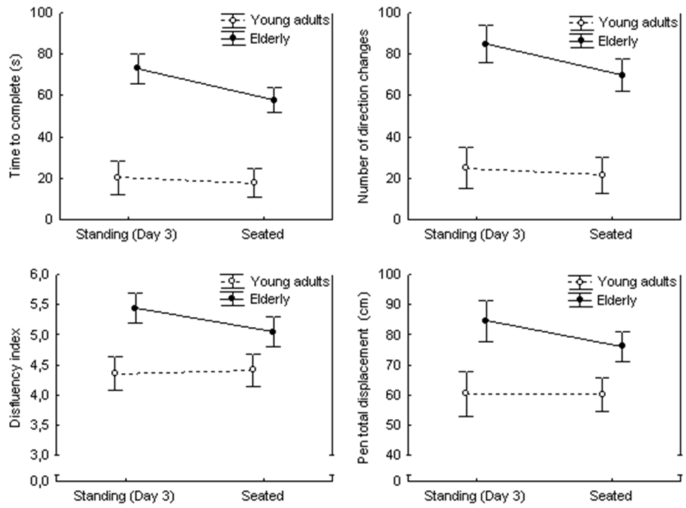

Figure 1. Tracing performance for the standing and seated trials of Day 3 for the young and older people.

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DOES A FEAR OF FALLING INFLUENCE VESTIBULAR-EVOKED BALANCE RESPONSES?

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Introduction

Fear of falling, concern for a fall, is experienced by many people in a situation that is perceived as a threat, such as being exposed to height, and is a complex construct of many interacting factors such as emotion, sensory information and perception. However, little is known about the influence of fear of falling on involuntary balance reflexes and balance control in general. To maintain balance the input from the sensory modalities is of great importance, like input from the vestibular organs. Here, we investigate whether a fear of falling modulates balance reflexes evoked by galvanic vestibular stimulation (GVS) [1].

Methods

Height is an established paradigm to induce postural threat and investigate the influence of fear of falling on balance and control. Nine subjects (age: 42 ± 15 yrs (mean ± SD), 5 ♂, 4 ♀) stood with eyes closed on a 22 cm wide walkway at ground level (low postural threat) and 3.85 m off the ground (high postural threat) while the responses evoked by GVS were recorded. Markers positioned on the head were recorded with two CODA mpx30 scanner units (Charnwood Dynamics, Rothley, UK) and used to calculate the sway response. Galvanic skin conductance was recorded as a measure of physiological arousal [2, 3].

Results

Galvanic skin conductance almost doubled while standing in the high postural threat condition, indicating that postural threat was successfully introduced. Baseline sway was not influenced by standing at height. The initial ~800 ms of the response sway was unaffected by postural threat. But the peak vestibular-evoked sway response was attenuated at height (peak displacement at height: 6.91 ± 3.35 mm; at ground level: GB 17.31 ± 11.24 mm (mean ± SD)) (figure 1). The peak displacement was attenuated by a reduction in sway velocity, but the position error was not corrected until after the stimulus.

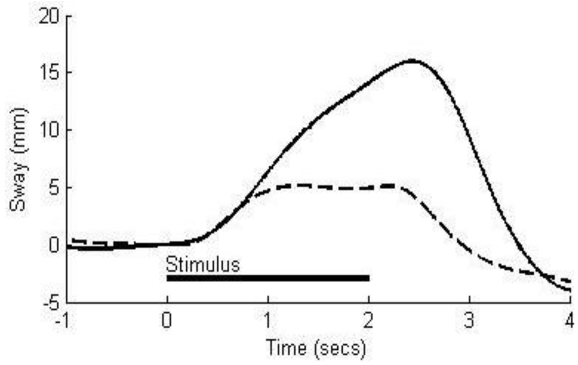

Figure 1. GVS-evoked sway when standing at ground level (solid line) and at height (dashed line).

Conclusions

These results demonstrate that although body displacement can be minimized during a vestibular-evoked sway response, vestibular reflexes are initially unaffected by postural threat. Thus, control motivated by fear of falling is mediated by sensory integration mechanisms with a longer timescale than the reflex vestibular responses. These mechanisms are sensitive to dynamic rather than static non-visual, non-vestibular information, minimising sway velocity rather than restoration of position.

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ARE TASK PERFORMANCE AND EXECUTION ON A ONE-LEGGED STANCE TASK INFLUENCED BY POSTURAL THREAT?

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Introduction
Postural threat, induced by height, increases the demand on the locomotor system. It is known that gait changes occur when people walk at height. It is unknown whether these reflect actual reduction in balance ability. It is known that difference in movement behaviour can be observed in complex movement under anxiety [1]. Showing the importance of not only investigating the performance of a task is affected but also the execution of the task. Here we compared the ability to perform a one-legged stance task under two different levels of postural threat and investigate the strategy to complete the task to evaluate if balance ability is indeed affected.
Methods
We asked eight healthy participants (age: 36 ± 12 yrs (mean ± SD), 4 ♂, 4 ♀) to perform a one-legged stance task on a 22 cm wide walkway at ground level (low postural threat) and on a 22 cm wide walkway raised 3.85 m above the ground (high postural threat). Position data was recorded using a motion capture system (VICON, Oxford Metrics, UK). Electromyography (EMG) of the lower leg muscles (Delsys Trigno™ Wireless) as well as galvanic skin conductance (GSC) were recorded as analogue signals into the motion capture system. Using Visual 3D software (C-Motion, Rockville, MD) a full-body model was constructed, the model consisted 13 segments: two feet, two shanks, two thighs, two forearms, two upper arms, pelvis, trunk and head. Centre of mass (CoM) position was calculated as a weighted sum of each of these segments CoM and computed in the Visual 3D software. Also joint angles were calculated. The co-contraction index (CCI) for the ankle and knee was estimated. CCI was calculated as the overlapping area of the EMG curves for each muscle pair around the ankle/knee [2].
Results
Preliminary results showed an increase in GSC during the one-legged stance at height compared to the task at ground level indicating that postural threat was successfully increased at height. Measures of stability (CoM RMS and extrapolated CoM) showed no difference between the two tasks. However, postural configuration during the task was changed (hip angle of the stance leg and knee angle of the raised leg) indicating a different strategy to complete the task under postural threat. Furthermore, the CCI was increased during the one-legged stance task at height compared to the task at ground level. So the task at height was completed at a higher energetic cost. Moreover increased CCI is often associated with an increased stiffness, based on this assumption we would expect a reduction in the CoM movement, however this is not what we observed.
Conclusions
Postural threat did influence the execution of the one-legged stance task (postural configuration, co-contraction index) but did not influence task performance in terms of stability measures.

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COMPARISON OF STATIC POSTUROGRAPHY AND ACCELEROMETRY IN DIFFERENTIATING EARLY STAGE PARKINSON PATIENTS AND ELDERLY CONTROLS

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Introduction

Our recent study showed that static posturography is not sufficiently sensitive tool for detection of postural instability in early stage PD patients [1]. We hypothesize that accelerometry is able to differentiate between early stage Parkinson´s disease (PD) patients and elderly controls [2] more properly in comparison to static posturography.

Methods

We assessed 13 healthy elderly controls (mean age 70.5 years) and 12 early stage PD patients (mean age 63.7 years). Each subject was tested in four sensory conditions: stance on a firm surface with eyes open (EO); stance on a firm surface with eyes closed (EC); stance on a foam surface (thickness 10 cm) with eyes open (FEO) and stance on a foam surface with eyes closed (FEC). The subjects stood relaxed on the barefoot, with the head in a straight-ahead position, their arms along the body, the heels together and feet splayed at an angle of about 30º. During conditions with eyes open subject's eyes were focused on a stationary eye level visual target (a black spot with a diameter 2 cm). The duration of each record in each condition was 50 s, followed by a short rest period (1-3 min). Postural activity was assessed by CoP (centre of pressure) from force platform and trunk tilts measured by two accelerometers placed over vertebrae L5 and Th4. In each condition we evaluated and consecutively compared amplitude and velocity parameters of CoP and trunk tilts in lateral (x) and antero-posterior (y) directions.

Results

Posturography revealed significant difference between both groups only in the most difficult sensory condition (FEC). However, analysis of sway activity recorded with accelerometers distinguished both groups in several parameters in each sensory situation (Fig. 1). More clear difference between PD patients and healthy control in velocity of trunk tilts in lateral direction was showed in trunk tilts. In all parameters of significant difference, patients had higher values than controls.

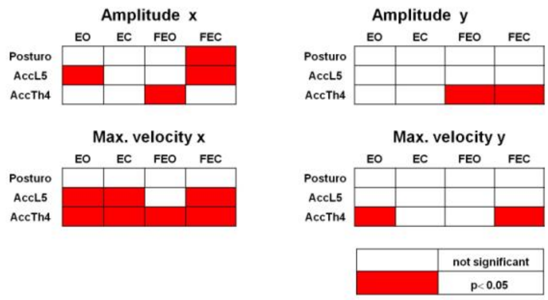

Figure 1. Presentation of significances (Student´s t-test) in comparison of both subject groups by data of posturography and accelerometry.

Conclusions

Accelerometry of trunk tilts is able to differentiate between early stage PD patients and elderly controls better than static posturography.

Acknowledgements: This project was supported by Scientific Grant Agency of the Ministry of Education of Slovak Republic and the Academy of Sciences (project 1/0070/11).

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REFRACTORINESS IN COMPENSATORY TRACKING OF AN UNSTABLE SECOND-ORDER LOAD

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Introduction

The prevailing understanding of sustained control of posture and external loads is that "closed loop" feedback mechanisms act continuously. However, more than 60 years ago, Craik [1] observed that the frequency bandwidth of a human operator is limited. He showed that with small inter-stimulus-intervals, the tracking responses to pairs of unpredicted, discrete step stimuli were refractory in nature. This finding suggested that the feedback loop can be intermittently "open" and leaves open the possibility that continuous peripheral and serial ballistic intermittent mechanisms are integrated to perform sustained tasks such as human balance [2]. Subsequently, it has remained unclear whether the observation of refractoriness would generalize to other conditions like higher load orders or different load stabilities. To investigate whether evidence exists for intermittency in the sustained control of an unstable load, such as during human balance, we employed a new method capable of revealing refractoriness in compensatory, visuo-manual tracking of an unstable second-order load.

Methods

Using a joystick, ten participants performed a compensatory, visuo-manual tracing task while controlling the position (displayed on an oscilloscope) of a second-order load with an unstable time constant equivalent to that of an upright standing human [3]. To answer the question whether the response to a second stimulus (RT2) is delayed compared to the response to the first stimulus (RT1), 32 paired step disturbances with 8 different inter stimulus intervals (ISIs) were added to the joystick signal as a motor disturbance. In order to quantify (even if the joystick movements are ongoing) the possible existence of refractoriness we focus on a simple question: Is it possible to improve (in the post-experimental analysis) the goodness of fit of an appropriate order, zero delay ARMA model relating the control signal to a series of paired stimuli step disturbances by sequentially and individually adjusting the instant of each step disturbance? If this procedure would result in an optimized (and thus better) fit, the adjustments to the first and second stimuli would provide us with distributions of first and second reaction times that enable us to test whether RT1 is equal to RT2 or whether RT2 is delayed relative to RT1.

Results

The optimized ARMA method showed that on average, RT2 was longer than RT1. Significant main and interaction effects of reaction times (RT1 vs. RT2) and ISI (0.15 – 4 s) were found (Fig. 1). Post-hoc test revealed that for ISIs greater than 550ms reaction times 1 and 2 were not significantly different, but for ISIs less than or equal to 550ms RT1 and RT2 diverged significantly.

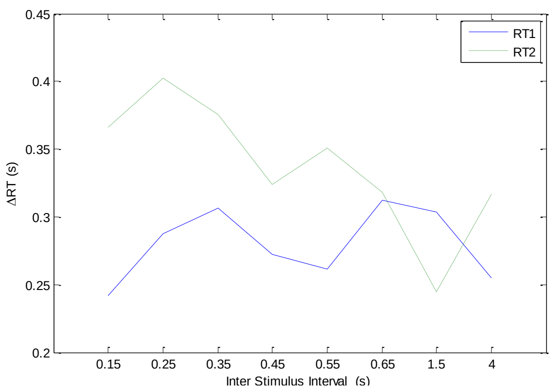

Figure 1. The interaction between reaction times (RT1 vs. RT2) and inter stimulus intervals.

Conclusions

Constructing an ARMA model and adjusting the first and second reaction times improved its explanation of the data. These reaction times were not constant as one would expect based on a continuous control model. Moreover, our method revealed a systematic difference between RT1 and RT2 indicating that when stimuli follow closer than or equal to 550 ms one after the other, the response to the second stimulus is interfered by the response to the first stimulus. These findings suggest that also for the control of an unstable second-order load, responses are refractory in nature. These findings might be better explained by an intermittent control model than by a continuous control model.

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A DECREASE IN SHORT-RANGE ELASTIC STIFFNESS CAUSES A DROP IN PHYSIOLOGICAL FINGER TREMOR FREQUENCY

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Introduction

There is a long-lasting debate on the origin of oscillations in limbs under a postural condition. This physiological tremor is attributed to either neural factors (e.g. central or spinal neuronal oscillation) or mechanical factors (e.g. resonance) [1]. Recently, it was shown that the single peak frequency of hand tremor increased after movement despite unchanged EMG arguing for a mechanical effect caused by a history dependent increase in limb stiffness [2]. Here we attempt to determine the role of mechanical resonance in finger tremor. Rather than comparing EMG and tremor as before, we evoked finger movement by direct muscle stimulation, thus bypassing the nervous system.

Methods

We investigated the characteristics of electrically-evoked finger tremor during isotonic and isometric conditions. Acceleration and force responses to electrical stimulation of the finger extensor muscle were recorded in five healthy participants (4 male, age range 21-64). We either measured vertical acceleration of the relaxed, splinted middle finger (isotonic condition) with an accelerometer or recorded the exerted vertical force while the middle finger was splinted to a strain gauge (isometric condition). In both situations, a filtered white noise train of stimuli (frequency range 2 - 30 Hz, 60 s in duration) was delivered to the otherwise relaxed extensor communis digitorum muscle at five different stimulus intensities. These intensities were individually determined based on acceleration response and ranged from just visible to a response of 15 m/s^2 (mean values 28mA, 33mA, 35mA, 42mA and 47mA). We calculated Fast-Fourier Transforms for the stimuli (input) and for both the acceleration and the force of the finger (output) as well as the cross spectral gain between the stimuli and both of the output signals.

Results

Analysis confirmed a white noise spectrum for the stimulus. For low stimulus intensities the gain between stimulus and acceleration showed a peak at ~22 Hz (Fig. 1). With increasing stimulus intensity the amplitude of the gain increased and the peak frequency decreased to ~14 Hz ($p < 0.001$). Additionally, a second peak at ~ 9 Hz arose. In contrast, during the isometric condition, stimulus intensity increased the overall force gain uniformly across all frequencies, without affecting the location of the peak frequency.

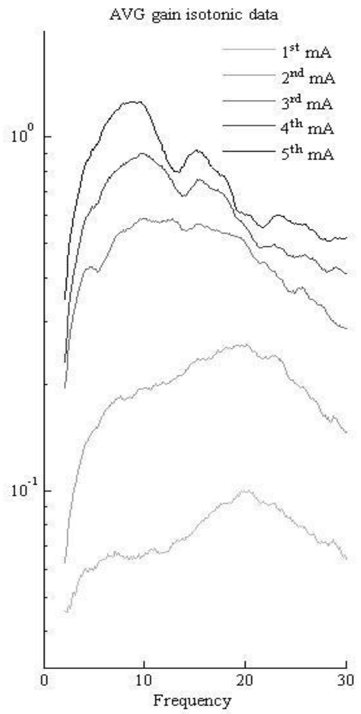

Figure 1. Gain between muscle stimulation and finger acceleration for five stimulus intensities, during the isotonic condition (1-5).

Conclusions

We observed a decrease in peak frequency with increasing stimulus intensity during isotonic, but not isometric conditions. These findings are consistent with a mechanical origin of physiological tremor, with the peak acceleration frequency of the finger determined by its stiffness and inertia. The reduction in frequency can be explained by a decrease in the short-range elastic stiffness of the finger muscles as larger stimuli evoke greater muscle movement.

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THE EFFECT OF BALANCE TRAINING ON PARAMETERS OF POSTURAL STABILITY AND STRENGTH IN ATHLETES AFTER ANTERIOR CRUCIATE LIGAMENT INJURY

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Introduction
This work was focused on design and evaluation of the effect of 12-weeks of training on balance boards on parameters of balance and strength in athletes after anterior cruciate ligament injuries.
Methods
A group of 16 individuals, mainly soccer players, divided into experimental (EG) and control group (CG) participated in the study. While EG used balance boards for the training, CG did the same training on stable surface. Static posturography was evaluated using tests of static balance and task-oriented balance tests. Strength was evaluated by means of exercise bouts on isokinetic cycle ergometer.
Results
Results showed significant improvement of postural stability in EG during stance on injured leg and on both legs with eyes open (EO) as well as eyes closed (EC). On the other hand, postural stability under such conditions in CG did not significantly changed. Mean power during exercise bouts on isokinetic cycle ergometer increased significantly in both groups, however while in EG during all revolution rates (60, 80, 100 and 120 per minute), in CG only during 100 and 120 rpm, which in both cases resulted in decreased laterality. It may be concluded that training on balance boards is more efficient in terms of improvement of postural stability and power, which may be also corroborated by gains in these parameters, than training on stable surface.
Conclusions
12 weeks of training on balance boards has significantly improved balance in terms of decreasing mean COP velocity during stance support surface with EO and EC. Gain in balance improvement was greater on injured leg in EG than in CG. 12 weeks of balance training led to more precise perception of COM position and regulation its movement in medio-lateral direction during visually-guided COM tracking task in EG than in CG. Both training programs led to decreasing of muscular deficit between injured and noninjured leg to 10% in all subjects.

Keywords: *laterality, injuries of anterior cruciate ligament, postural stability, training, power*

THE EVALUATION OF POSTURAL CONTROL IN CHILDREN AND YOUTH DIAGNOSED WITH IDIOPATHIC SCOLIOSIS

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Introduction

Idiopathic Scoliosis (IS) is the most prevalent type of spinal deformity observed in children and youth, and is characterized by a profound 3D curvature of the spine. Previous work has provided insight into the association of age, skeletal maturity, gender and family history as factors related to the progression of the spinal deformity. However, still today, it is unknown why the spinal deformity of certain children and youth progress and require surgical intervention [1]. Although recent work has revealed the extent of postural deformity of the adjacent skeletal structures to the spine (pelvis, thorax) [2, 3, 4], there is limited evidence that has linked observed dysfunction in postural control to disease progression. The relevance of this gap in the literature has been brought to light in a recent 'vicious cycle' hypothesis that links dysfunctional neuromuscular control of the trunk and paraspinal muscles, with asymmetric vertebral loading, asymmetric vertebral growth and the progression of the curvature of the spine [1]. Within this context, the overall goal of our present work is to develop new models to assess the neuromuscular control of posture and mobility in children diagnosed with IS [2, 3, 4]. The development of these new models will provide the foundation to explore the causal link between neuromuscular dyscontrol, mechanical loading of the spine and progression of the spinal curvature. The specific objectives of this current project is to develop new models that will a) provide an accurate estimation of the Centre of Mass (COM) that is independent of the severe postural deformities that accompany IS; b) evaluate the neuromuscular control of trunk mobility and stability.

Methods

Ongoing work in our lab has focused on the postural assessment of able bodied participants (n =10; 5 female, 5 male), and youth diagnosed with IS (aged 8-16) (n = 7; 5 female, 2 male). Postural control was assessed while the participants were sitting, standing, performing a lateral trunk flexion, and walking. Each assessment included the 3D tracking of 31 markers located on the participant´s arms, trunk, pelvis and lower extremities with a 7 Camera Vicon Mx motion capture system. A Delsys Myomonitor IV wireless/data logging EMG system recorded the timing and asymmetry of the thoracic, thoracolumbar and lumbar paraspinal muscles. A multi-axial force plate was used to quantify the position and displacement of the Centre of Pressure (COP), and COM. The Delsys Myomonitor IV system recorded trunk muscle activity, trunk position and acceleration as participants performed activities of typical of daily living in everyday life.

Results

Initial analysis has focused on quantifying the dynamics of postural control when sitting, standing and walking, and the ambulatory profile of participants as they engaged in an unscripted daily activity task. This has revealed important differences between standard kinematic models that estimate the position of the COM to that estimated from a force plate. It has also revealed important dyscontrol of the trunk as evidenced by unsynchronized EMG activity of the paraspinal muscles during lateral trunk flexion and walking.

Conclusions

This ongoing work has brought to light novel perspectives about the complexity of the postural dyformities and associated dysfunction to the control of balance that accompany progressive IS. Future work is focused on the application of the methods developed in this research to be applied within the context of a longitudinal study focused on further understanding the primary determinants of progression in IS.

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POSTURAL CONTROL AND ACTIVE VIDEO GAMES: POTENTIAL THERAPEUTIC APPLICATIONS

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Introduction
In recent years, virtual reality (VR) has served as a fundamental tool to probe the underlying neural control mechanisms involved in the maintenance of postural control and dynamic stability while walking. The advantage of VR for this purpose has related to the precise control of features in the surrounding environment, including the timing of visual, auditory and mechanical stimuli [1]. However, the application of VR systems within a rehabilitative environment is somewhat restricted, in part due extensive operational resources. A more accessible option for clinical settings has emerged in the form of active video gaming platforms that engage user interaction through upper and lower extremity movements [2]. Prior to the clinical application of these devices, it is warranted to evaluate if these games elicit appropriate balance control strategies. The purpose of this study was to evaluate postural control strategies that are elicited when an individual engages with an active video gaming console.

Methods
To address this objective, young able bodied adults (n = 16, aged: 25±2 yrs) were recruited to participate in this study. Each participant was requested to play the Nintendo Wii Fit™ videogame. This game is composed of an instrumented balance board that contains multiple sensors that measure the participant's change in weight distribution while standing. The distribution of body weight then serves as the controller of the avatar that is embedded within the gaming console. For this study, each participant played 10 trials of Ski Slalom and Soccer Heading respectively. These two games were chosen based on their potential to engage the participant to perform potentially useful exercises that may compliment a therapeutic balance training program. The 3D segment movement of each participant was recorded with a 16 camera Vicon Mx system; an AMTI multi-axial force plate recorded forces exerted through the balance board; a Delsys Myomonitor IV system recorded EMG bilaterally from the lower extremity and paraspinal muscle groups.

Results
Initial analysis has focused on identifying changes in strategies used by the participant between the first and last trial, and also between games. While there was no difference in medial-lateral Centre of Pressure (COP) variability between games after one trial, there was a significant difference after ten trials. Across trials, COP variability increased (59 to 75 mm) for Soccer Heading while it decreased (67 to 33 mm) for Ski Slalom. For skiing participants demonstrated decreased shoulder and pelvic movement combined with increased pelvic-shoulder coupling. Conversely, participants demonstrated greater initial shoulder tilt when playing soccer with no reduction in pelvic rotation and tilt. Therefore, participants decreased pelvic and trunk movements when skiing, suggesting a greater contribution of the lower extremity to control posture, while they primarily used a lateral tilting trunk strategy to play soccer. To further explore the underlying control mechanisms that are adopted with these games, ongoing analysis is focused on quantifying: 1) latency and amplitude of upper/lower extremity EMG activity; 2) symmetry of COP displacement; 3) COM displacement.

Conclusions
Overall participants adopted a unique strategy to play each videogame. As such, Ski Slalom may be an appropriate game to engage an ML weight shifting strategy while Soccer Heading may be an appropriate game to challenge the limits of stability while practicing lower limb and trunk dissociation. Prior to its implementation in the rehabilitation setting, further studies should assess if these learned strategies are retained and if improved game performance correlates with improvement on standardized balance measures.

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AMBULATORY MONITORING OF ASSISTIVE DEVICE USE: NOVEL APPROACHES TO ASSESSING COMMUNITY AMBULATION IN NEUROLOGICAL POPULATIONS

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Introduction

Individuals with neurological disorders, such as multiple sclerosis (MS), often experience gait impairments that limit their mobility [1]. Assistive mobility devices are, thus, frequently employed to compensate for their impairments [2]. In spite of assistive device use, falls continue to be a major concern for these individuals as they ambulate about the community with their devices. As a result, there is a need to better understand the factors that contribute to this increased falls risk in order to determine how these adverse events can be prevented. The ambulatory monitoring of gait parameters during rollator use (e.g. foot placement patterns, walker loading forces, walking speed and upper trunk accelerations) can provide an objective glimpse into the facilitators and barriers to safe mobility for rollator users in the community. The purpose of this study is: a) to quantify the foot placement characteristics (i.e. step width and step width variability) of individuals with MS in relation to their environmental context; b) to explore how the walker loading patterns and upper trunk accelerations of these individuals can be monitored to learn more about their stability in different environments.

Methods

Ten women diagnosed with MS, who used rollators regularly, participated in this study (n=10). The gait characteristics of these individuals were measured with an instrumented rollator (i.e. iWalker) and a tri-axial accelerometer as they walked along a pre-determined outdoor course through an urban downtown environment. Features of the environment that they encountered included: 1) an urban sidewalk; 2) an up-ramp; 3) a down-ramp; 4) a busy intersection crossing. The iWalker consisted of a standard rolling walker (Invacare Dolomite AB, Sweeden) that had been fitted with a portable digital video camera to capture foot placement characteristics (e.g. step width and step width variability), an optical encoder in the wheels to estimate walking speed, as well as load cells to quantify vertical loading forces and the distribution of those forces (e.g. centre of pressure of the hands). A Microstrain G-Link® wireless accelerometer (Microstrain Inc., U.S.A.) was placed over C7, in order to measure three-dimensional accelerations and the inclination of the upper trunk.

Results

A repeated-measures analysis of variance revealed that SW variability ($F[4, 28] = 7.224$, $p<0.001$), but not SW ($F[4, 28] = 1.317$, $p=0.288$), was influenced by the walking environment. Post-hoc analysis (pairwise comparisons using Bonferroni adjusted t-tests) revealed differences between the in-lab vs. up-ramp conditions ($p=0.012$), and up-ramp vs. down-ramp conditions ($p=0.027$). Ongoing analysis is focused on quantifying the vertical forces exerted through the walker frame and accelerations of the trunk, as measured by the load cells and accelerometer respectively. Of specific interest is to analyze these patterns in relation to environmental contexts and transient moments of instability.

Conclusions

The foot placement patterns of rollator users with multiple sclerosis can be affected by the walking environment in certain circumstances. Further analysis of the walker loading patterns and upper trunk accelerations of these individuals may enhance our understanding of the determinants of safe mobility for rollator users in the community.

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POSTURAL STABILITY OF VISUALLY IMPAIRED CHILDREN

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Introduction

The aim of the study was to assess balance abilities in visually impaired children during different types of standing positions. Sight plays a dominant role in balance abilities as coding and processing of other sensory information [1]. Sight is not essential to maintain an upright standing position, the one can stand in the dark, but standing stability decreases with visual control deprivation [2, 3]. Persons with visual impairments are able to use more other senses, e.g. touch and hearing, instead of vision.

Methods

Research sample consisted of 11 students of the high school for visually impaired students (age 16.9±4.4 year, body height 172.4±3.8 cm, body weight 70.9±4.6 kg). Whole range of participants' visual impairments was represented in the study. To assess postural stability we used a stabilometric force platform Footscan with frequency of 33 Hz. The length of the tests was 30 s for bipedal standing with eyes open and closed and standing on one foot with eyes open.

Results

Visual control deprivation in common population causes usually an increase of commonly evaluated parameters of postural stability. In our research sample, the value of fluctuation in the left-right direction during standing with eyes closed was 7.61±4.03 mm; in the anteroposterior direction it was 14.40±10.46 mm. The overall trajectory of TTW (total travel way) was 344.36±87.88 mm, which means a deterioration of 44.96 mm compared to the standing with eyes open. Differences between fluctuations in left-right and anteroposterior directions were only 0.68 mm, or 0.85 mm respectively. During a narrow standing position with eyes open, fluctuation parameters slightly changed; in the left-right direction it was only 1.12 mm and in the anteroposterior direction 1.76 mm. Overall trajectory was thus prolonged by 73.85 mm. On the basis of these values, we can assume that deprivation of visual control does not cause any significant changes. Standing on one foot was the most difficult test and the overall trajectory was shorter in the right foot by 777 mm compared to the left one, which makes a difference of approximately 30%.

Conclusions

Visual control exclusion indicates a minimal decrease in the examined parameters. In the monitored group, increased ability of so called "sensory reweighting" was found in participants with a higher degree of visual impairment. The results confirm the uniqueness of the examined group, when the healthy participants demonstrated lower oscillations during the standing with eyes open [4]. This confirms the fact that the change of standing quality depends on many other factors, such as the width of the standing, type of the base of support and availability of other sensory perceptions [5].

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POWER OUTPUT IN CONCENTRIC PHASE OF CHEST PRESSES IN ATHLETES WITH DIFFERENT EXPERIENCE WITH INSTABILITY RESISTANCE TRAINING

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Introduction

It has shown [2, 3] that unstable support base compromises power in concentric phase of chest presses, namely at higher weights lifted [4]. However, this has been documented only in physically-active individuals without experience with instability resistance training. On the other hand, there is lack of studies dealing with athletes applying instability devices, such as exercise balls or wobble boards into the training routine. Preliminary results [1] indicate that these subjects are able to utilize spring properties of the ball and enhance power in concentric phase of lifting. In order to prove this observation, the aim of the study was to compare peak and mean power in concentric phase of chest presses at different weights lifted with back supported by unstable Swiss ball in athletes with different experience with instability resistance training.

Methods

Two groups of experienced lifters participated in the study. While group 1 (n = 17, age 23.1 ± 2.4 y, height 186.4 ± 8.7 cm, weight 79.8 ± 8.5 kg) had experience only with conventional resistance training, group 2 (n = 16, age 24.0 ± 2.6 y, height 182.6 ± 5.9 cm, weight 76.9 ± 9.1 kg) had experience with resistance exercises on unstable support surfaces. They performed in random order barbell chest presses on a Swiss ball with weights of 40%, 60%, and 80% 1RM, respectively. Exercises were performed with countermovement using maximal effort in concentric phase. A system FiTRO Dyne Premium based on precise analogue velocity sensor with sampling rate of 100 Hz was used to monitor basic biomechanical parameters involved in lifting exercise. Force is calculated as a product of mass moved and the sum of an instant acceleration and gravitational constant. The acceleration is obtained by derivation of velocity, registered by rotating analogue sensor coupled with the barbell by means of nylon tether. Power is calculated as a product of force and velocity. Peak and mean values of power in acceleration and entire concentric phase of lifting were analyzed.

Results

While there were no significant differences in mean power in entire concentric phase of chest presses performed on a Swiss ball in group 1 and 2 while lifting weights of 40% 1RM (332.6 ± 57.2 W and 371.6 ± 56.7 W, respectively) and 60% 1RM (359.7 ± 60.5 W and 407.3 ± 64.9 W, respectively), its values were significantly ($p<.05$) lower at 80% 1RM in group 1 than group 2 (310.6 ± 51.6 W and 367.8 ± 56.5 W, respectively). However, mean power in acceleration phase of lifting was significantly lower in group 1 than group 2 at all weights lifted, 40% 1RM (503.6 ± 70.4 W and 556.8 ± 82.6 W, respectively; $p<.05$), 60% 1RM (532.6 ± 72.2 W and 590.9 ± 84.0 W, respectively; $p<.01$), and 80% 1RM (365.5 ± 66.5 W and 452.8 ± 72.1 W, respectively; $p<.01$). Also peak power was significantly lower in group 1 than group 2 at 40% 1RM (691.4 ± 90.4 W and 742.9 ± 110.6 W, respectively; $p<.05$), 60% 1RM (712.7 ± 100.2 W and 774.3 ± 114.0 W, respectively; $p<.01$), and 80% 1RM (518.7 ± 86.5 W and 594.1 ± 92.1 W, respectively; $p<.01$).

Conclusions

Power output in concentric phase of chest presses performed on a Swiss ball is lower in subjects without than with experience with instability resistance exercises. These differences can be mainly seen in peak and mean power in acceleration phase of lifting with higher weights (≥ 60% 1RM). These findings indicate that the ability to produce power during weight exercises on unstable support surface depends on training background.

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SPORT-SPECIFIC ASSESSMENT OF BALANCE

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For many years our research has been centered on issues dealing with sport-specific balance testing [3]. Postural stability has been usually assessed under static conditions, however, these seems to be not sensitive enough to differentiate athletic balance level. Lower sensitivity of static posturography is a consequence of multiple sensory inputs (visual, vestibular and proprioceptive) involved in postural control. Such a system can compensate smaller impairment of balance in such a way that under normal conditions (quiet stance) no deficits in postural stability may be apparent. Under dynamic conditions (stance on unstable surface), the control mechanism is taxed to a substantially higher extent so that individual differences can be revealed. However, though in current practice various dynamic posturography systems are available, most of them have shortcomings. First, some of the platforms, even the largest and fastest motions producing, are insufficient to destabilize subject beyond its stability limit. Though being very suitable for the elderly and patients with deteriorated coordination, in highly skilled athletes does not cause serious balance impairments. Second, many of them produce only unidirectional movements, usually in antero-posterior plane. Furthermore, in some cases the learning effect has been observed using tilted platforms since relatively high predictability of the subjects to upcoming perturbations. To avoid these drawbacks one should use more sophisticated methods closer to balance function. Promising seems to be task-oriented balance tests, such as visually-guided COM target-matching task or visually-guided COM tracking task. In the first case, subjects have to hit the target randomly appearing in one of the corners of the screen by horizontal shifting of COM in appropriate direction while standing on spring-supported platform equipped with PC system for feedback monitoring of COM movement. The system registers time, distance, and velocity of COP trajectory between stimulus appearance and its hit by horizontal shifting COM. In the second, subjects are provided by feedback on COM displacement on a computer screen while standing on dynamometric platform. Their task is to trace, by shifting COM, a curve flowing either in horizontal or vertical direction. The deviation of instant COP position from the curve is recorded at 100 Hz by means of the system FiTRO Sway Check. These tests have been also used to assess balance under both laboratory and sport-specific conditions. There are several sports where static and/or dynamic balance is one of the limiting factors of performance. Its impairment can not only affect the outcome, but may also increase the risk of injuries. Therefore, rapid readjustment of balance after sport-specific exercise to baseline is considered an important ability. Our research interest was the understanding of physiological mechanisms of post-exercise balance impairment [1]. It has been found that postural sway response a) to exercises such as cycling and running depends on its type, intensity, and duration, and b) to resistance exercises also on additional load used, rate of movement, number of repetitions and sets, muscle mass activated, and intensity of proprioceptive stimulation. As possible physiological mechanisms of post-exercise balance impairment identified so far may be: fatigue, hyperventilation, deterioration of functions of mechanoreceptors, proprioceptors, vestibular apparatus and visual cues, muscle damage, dehydration, hyperthermia, and dizziness. Besides this, we also investigated the effect of different forms of intervention on balance [2]. The question was whether development of more precise proprioceptive acuity using serial mechanical proprioceptive stimulation or task-oriented sensorimotor exercises contributes to better postural stability or whether enhancement of ability to maintain balance under dynamic conditions after instability agility or resistance training improves proprioceptive acuity. However, the results often depended on the test in which subjects were measured. Therefore, future work should be directed toward exploring novel alternatives of measurement of balance during functional task. An accelerometry may be a valid quantitative measure of postural sway that is more strongly related to task-based measured. Implementation of accelerometry in combination with stochastic dynamics may allow quantify the time-varying structure of postural sway pattern. Such diagnostic tools may be implemented not only in laboratory but also field-testing of balance.

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