ABSTRACTS

OF THE 7TH INTERNATIONAL

POSTURE SYMPOSIUM

Massimo Cenciarini Tomas Maly Christopher McCrum Marketa Hamrikova Joost van Kordelaar Vesa Linnamo Carlijn Vernooij Lennie Gandemer Vassilia Hatzitaki Miroslav Janura Dorota Drabarek Matthew Bancroft Agnieszka Szczęsna Martin Cerny Adam Switonski Fotini Arabatzi Max Wuehr Robert Peterka Fay Horak Jeffrey Hausdorff James Frank Thomas Mergner Jantsje Pasma Jana Krohova Lorenz Asslaender Plamen Gatev Henrike Fischer Martin Lakie Frantisek Zahalka Maros Smondrk Alexander Meigal Ludmila Gerasimova-Meigal Kai Boetzel Charalampos Sotirakis Jean Louis Honeine Frantisek Hlavacka Zuzana Hirjakova Jana Lobotkova Kristina Buckova Csilla Haburcakova Brian Day Julian Decker Alexander Aruin Henryk Josinski Thomas Kienbacher Gerold Ebenbichler Peter Reeves Katerina Kirilova Fariba Yadolahi Irene Di Giulio Lorenzo Chiari Helena Singliarova Janusz Błaszczyk Eliska Kubonova Christoph Maurer Boris Barbolyas Peter Valkovic Cauchy Pradhan Tomas Gryc Marketa Prochazkova Claude Pothrat Marian Saling Martin Kucharik Tomas Lukac Stuart Mackenzie Ingrid Schut Zdenek Svoboda Roman Melecky Saskia Steinl Martina Chvostekova Anna Liedtke Lucia Bizovska Raymond Reynolds Urban Fietzek Chris Dakin Erika Zemkova Zuzana Kosutzka

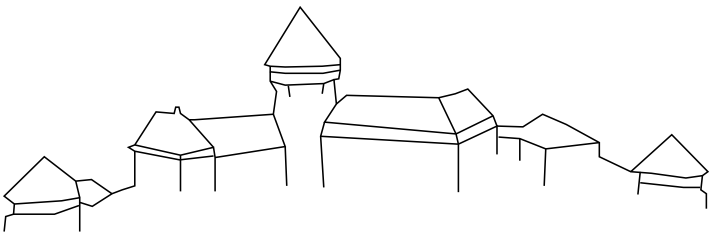
SMOLENICE CASTLE

SLOVAKIA

SEPTEMBER 6 - 9, 2015

INSTITUTE OF NORMAL AND PATHOLOGICAL PHYSIOLOGY
SLOVAK ACADEMY OF SCIENCES

7TH INTERNATIONAL
POSTURE SYMPOSIUM



SEPTEMBER 6-9, 2015
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ABSTRACTS OF THE 7TH POSTURE SYMPOSIUM

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Smolenice Castle, Slovak Republic, September 6-9, 2015

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Jana Lobotková

Reviewers: Diana Bzdúšková
Erika Zemková
Peter Valkovič

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Institute of Normal and Pathological Physiology
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	Sienkiewiczova 1, Bratislava
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15:30	Registration and accommodation in Smolenice Castle
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	Director of Institute of Normal and Pathological Physiology, Slovak Academy of Sciences
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ABSTRACTS

Training-related enhancement of anticipatory postural adjustments in older adults

A.S. Aruin, N. Kanekar, S. Jadghane

University of Illinois at Chicago, Chicago, USA
Email: aaruin@uic.edu

Introduction

Impaired generation and utilization of anticipatory postural adjustments (APAs) is one of the reasons for postural instability in older adults [1]. We investigated the effects of APA-focused training in enhancing APAs for balance control of the elderly.

Methods

Two groups of older adults participated in single-sessions of training involving either external perturbations (catching a medicine ball) or internal perturbations (throwing a medicine ball). Another group participated in four-week training with ball catching. The subjects were assessed before and after training using predictable external perturbations induced by a pendulum with impact applied to the shoulders [1]. EMG activity of the thirteen trunk and leg muscles, 3-D body kinematics, and ground reaction forces were recorded during the times typical for the anticipatory and compensatory phases of postural control. EMG latency, center of pressure (COP), and center of mass (COM) displacements were obtained.

Results

Following training with ball catching, significantly early APA onsets ($p > 0.05$) were seen in six muscles and the eventual peak displacement of the body's COP and COM after the impact were smaller, indicating improved postural stability (Fig. 1). Similarly, following training with ball throwing, postural activity in anticipation of the perturbation induced by the pendulum impact occurred earlier as compared to the pre-training condition [2]. After the four-week training using catching a medicine ball (experimental group), postural activity in anticipation of the perturbation occurred earlier as compared to the pre-training condition. There were no improvements in APAs at the end of 4 weeks in subjects included in the control group. A four-week APA-based training enhanced postural preparation and resulted in greater postural stability of older adults which was confirmed by improved outcomes of clinical tests of balance including Timed-Up and Go (TUG) test ($p < 0.05$), mean postural sway velocity when standing on one leg, and Activities-specific Balance Confidence (ABC) scale [3]. The transfer of the effect of APA-based training using ball throwing or catching was seen as significantly early onsets ($p < 0.05$) of postural muscles prior to the bilateral arm flexion, the task that was not a part of the training protocol.

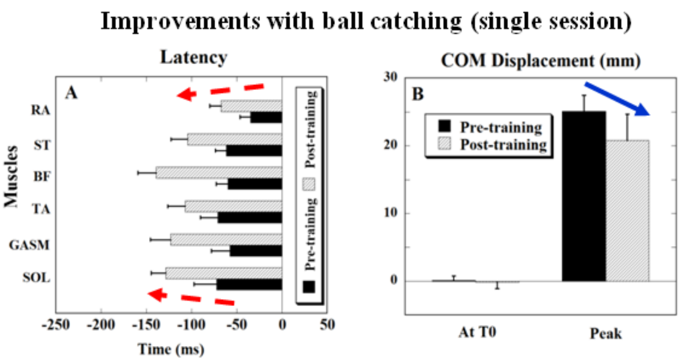

Figure 1 A Muscle latencies before the perturbation and **B** peak COM displacements during the balance restoration phase. Arrows show training-related improvement.

Conclusions

The APA-focused training enhanced anticipatory postural preparation and resulted in greater body stability following the perturbation. The outcomes, therefore, suggest that innovative APA-focused intervention could be used as an effective rehabilitation approach in improving postural control, functional balance, mobility, and quality of life in the elderly.

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Effect of Visual Cues on Trunk Stabilization During Support Surface Tilts

[1,2]**L. Assländer**, [1]G. Hettich, [2]A. Gollhofer, [1]T. Mergner

[1]University Clinics Freiburg, Neurocenter, Freiburg, Germany
[2]Albert-Ludwigs University, Institute for Sports and Sport Science, Freiburg, Germany
Email: lorenz.asslaender@sport.uni-freiburg.de

Introduction

Humans tend to stabilize the head in space when balancing with eyes open [1]. The neural control mechanism that is stabilizing the head is still not well understood. Using the Disturbance Estimation and Compensation, DEC model [2], previous work was able to describe human sway responses of the whole body center of mass (COM_B) with eyes closed and with eyes open, where adding visual cues reduced sway responses by improving disturbance estimates [3]. For eyes closed, the model has also successfully been extended to describe human trunk control [4]. While the visual effects on COM_B control can be described quite well by changes in model parameters, previous observations suggest a functional change in trunk control when adding visual cues. The current study aims to identify the presumed trunk control mechanism during eyes open.

Methods

Anterior-posterior sway responses of 7 subjects (aged 27.1 ± 3.6 years, 3 male) to unpredictable pseudo-random tilt perturbations with a broad frequency spectrum were measured with four stimulus amplitudes (peak-peak 1°, 2°, 4° and 8°) and the three visual conditions: (i) eyes closed (no visual cues), (ii) eyes open with stroboscopic illumination (only visual position cues), and (iii) eyes open with continuous illumination (visual position and velocity cues). Subjects leg and trunk body sway were measured using markers at hip and shoulder level. Head sway (angle between a virtual line from head to ankle and the gravitational vertical) and COM_B sway were calculated thereof. Model simulations were performed using double inverted pendulum dynamics and the extended DEC control model [4].

Results

Human head sway responses were smaller as compared to leg and COM_B sway across all visual conditions and stimulus amplitudes. During eyes closed and stroboscopic illumination, the reduced head sway resulted from a more upright position of the trunk as compared to the legs. In contrast, during continuous illumination trunk swayed beyond the upright position, i.e. forward (backward) leg excursions were associated with backward (forward) trunk excursion. This pattern resulted in a remarkable saturation, where head sway did not increase with increasing stimulus amplitude. To mimick this pattern observed in continuous illumination in the simulations, a functional change had to be introduced in the control model. Simulation results showed, that an additional compensation loop in the model can reproduced the pattern. The loop uses visual translation and orientation cues to estimate the hip translation and compensates the hip movement by a corresponding trunk lean command. Using this mechanism, simulations reproduced the trunk sway pattern observed during continuous illumination.

Conclusions

Model simulations suggest that humans achieve the head stabilization through A) an estimation of the hip translation based on visual cues, and B) a conversion of the hip translation to a desired, compensatory trunk lean angle. This mechanism could not be identified during stroboscopic illumination (only visual position cues), suggesting that the mechanism depends on visual velocity cues (optic flow).

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ONLINE ADJUSTMENT OF GAIT INITIATION BEFORE FOOT–LIFT

M.J. Bancroft, B.L. Day

University College London (UCL) Institute of Neurology, London, United Kingdom
Email: matthew.bancroft.13@ucl.ac.uk

Introduction

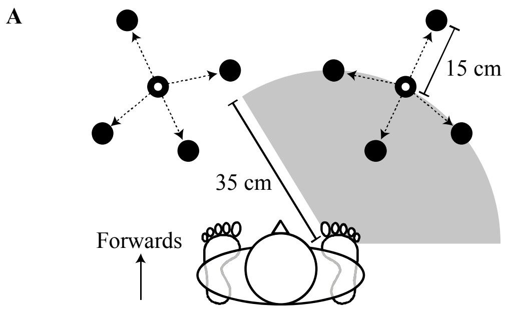
Vision is important for adjusting ongoing movements during gait initiation and locomotion. Once the foot lifts off the ground, vision can guide the foot towards its intended target and correct foot trajectory at short latency (~120 ms) [1]. The role of vision prior to foot–lift is currently unclear however. In normal stepping, the body is 'thrown' with appropriate momentum before foot–lift to allow a controlled fall of the body towards its intended target during the step [2]. Here we test whether the body 'throw' before foot–lift is adjusted online using vision.

Methods

Ten healthy, young subjects were asked to step as accurately as possible to a visually presented target (Fig. 1A). The target would either stay in the same location or unpredictably jump to a new location shortly after initiation of the 'throw' (95 ± 23 ms latency; mean ± SD). Jump target locations were oriented so that either step length or direction required alteration.

Results

When no target jump occurred, different 'throws' were used when stepping to different target locations. When a target jumped, the first adjustment to the step occurred during the 'throw' for all subjects. This was typified by a uniform reduction in the forward acceleration of the body, even when an increased acceleration for a longer step was required (Fig. 1B). On average, adjustment latency was 233 ± 32 ms. After this uniform response, a different acceleration was produced when stepping to different target locations, coupled with a delay in foot–lift.



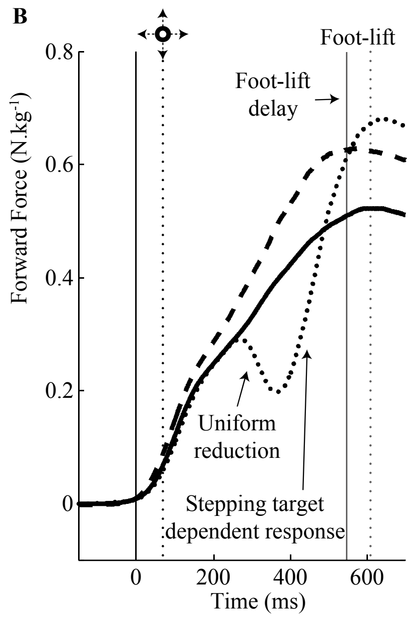


Figure 1 A Positions of the stepping targets. For target jump trials, the central target (unfilled circle) would initially illuminate before jumping to another location (filled circle). **B** Group data for the forward force (acceleration) produced during steps to the central target (continuous line), a longer step without a target jump (dashed) and a longer step with a target jump (dotted). Direction change and shorter steps are omitted for clarity. All traces are aligned to 'throw' initiation at time 0 (first vertical line). The first dotted vertical line denotes the mean time of the target jump. The time of foot-lift is denoted by the grey vertical line (continuous = no target jump, dotted = target jump).

Conclusions

We conclude that the body 'throw' before foot–lift is adjusted online using vision, even though adjustment could have been made after foot–lift. The presence of a foot–lift delay and stepping target dependent adjustment suggests that the body 'throw' before foot–lift is functionally important in developing a controlled fall of the body after foot–lift. This offers a useful mechanism to correct ongoing movements in order to maintain balance during gait and aid precision stepping.

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POSTURAL SYSTEM ADAPTATION TO ACHILLES TENDON VIBRATION STIMULI - THE PILOT STUDY

[1]**B. Barbolyas**, [1]J. Chrenová, [3]K. Bučková, [2]M. Čekan, [2]B. Hučko, [1]L. Dedík

Slovak University of Technology in Bratislava, Faculty of Mechanical Engineering,
[1]Institute of Automation, Measurement and Applied Informatics,
[2]Institute of Applied Mechanics and Mechatronics, Bratislava, Slovakia,
[3]Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia
Email: boris.barbolyas@stuba.sk

Introduction

Based on classification of postural responses to Achilles tendon vibration in 0, our pilot study was aimed to analysis of postural system autoregulation and identification of postural responses with respect of vibration stimuli frequencies and its duration.

Methods

Two healthy individuals were tested. Subjects were instructed to maintain bipedal quiet upright stance on firm surface with eyes open and closed. Stabilograms were recorded at 20, 60 and 80 Hz frequencies vibration stimuli on Achilles tendon with 20 s duration, and without stimuli. Measured data were processed by stabilogram analysis and developed Center of Pressure (CoP) trajectory length methods.

Results

Five phases of postural sway (Fig. 1) were identified. The phases 1, 3 and 5 present pseudo-steady states with quasi-constant velocity of CoP excursion. The phases 2 and 4 show characteristics of the first-order linear PI - proportional-integration system with gain $G_P = G_I$ for phase 2 and $G_P > G_I$ for phase 4. They are fast adaptation reactions of postural system with nonconstant CoP velocity to start and end of vibration stimuli, respectively. Phases 3 and 5 are slow pseudo-steady state phases to vibration stimuli start and end, respectively.

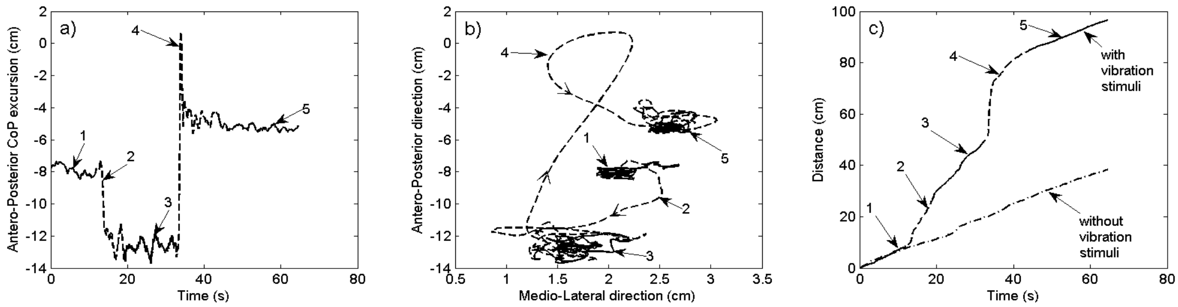

Figure 1 Stabilogram (a), statokinesigram (b) and displayed developed CoP trajectory length (c) of representative subject in situation eyes open with 60 Hz vibration stimuli. Full line - pseudo-steady state phase, dashed line - fast adaptation phase.

Conclusions

Applied method of developed CoP trajectory length includes the evaluation of individuals times phases of postural system autoregulation respecting the different stimuli intensity and duration. Stimulus represents deterministic disturbance input in postural system biofeedback control. Phases 2 and 4 with nonconstant CoP velocities closely correspond to postural system adaptation process after start and end of vibration stimuli. Different maximal CoP velocities after start and end of vibration stimuli suggest the postural system as nonlinear. Proposed method of signal processing allows detecting postural system adaptation capability and provides an alternative approach to quantifying the autoregulation control system in human beings.

Acknowledgements: This work was supported by VEGA grant (No. 2/0138/13 and No. 1/0604/15), Grant for support of PhD students 2015 of the STU (No. 1338), and the Philanthropic fund of Studio 727 Bratislava.

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DYNAMIC STABILITY ASSESSMENT DURING OVERGROUND AND TREADMILL WALKING

[1]**L. Bizovska**, [1]Z. Svoboda, [2]Z. Hirjakova, [1]M. Janura

[1]*Faculty of Physical Culture, Palacky University Olomouc, Olomouc, Czech Republic*
[2]*Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia*
Email: lucia.bizovska@gmail.com

Introduction

Many different approaches have been used for stability assessment during locomotion – traditional approach with kinematic and spatial-temporal characteristics [1], nonlinear analyses [2], frequency analyses [3] and others. These analyses are often used for signals recorded during treadmill walking trials, however, scientific studies showed that gait patterns in overground and treadmill conditions seem to be different [4]. The aim of this study was to verify whether dynamic stability variables computed by frequency and nonlinear analyses are different in overground and treadmill conditions in female groups.

Methods

Two female groups participated in this study – elder group (13 subjects, mean age 57.5 years), younger group (10 subjects, mean age 21.7 years). Walking protocol included 5 minutes walking overground and 3 minutes walking on the treadmill (TDW, LODE Valiant, Lode, B.V. Medical Technology, Groningen, Netherlands). Participants walked overground (OGW) with their preferred walking speed. Average speed for each participant was computed and set on the treadmill afterward. Signal from a 3D accelerometer (sampling rate 296.3 Hz, Trigno wireless system, Delsys Inc., Natick, MA, USA) placed on the L5 vertebra was recorded. Dynamic stability was assessed from 140 strides for all three axes using short-term and long-term Lyapunov exponents (LE), harmonic ratio (HR), multiscale entropy for scales 1 to 6 (MSE) and root means square of acceleration (RMS). Statistical analysis was performed in both groups using paired sample t-test, p-level was set as 0.05.

Results

The results showed that all short-term LE were significantly lower during TDW in both groups. Long-term LE were lower during OGW in both groups, significant differences were found in medial-lateral and vertical direction in younger group and in vertical and anterior-posterior direction in elder group. There were no significant differences for HR in younger group, whereas HR in medial-lateral and anterior-posterior direction were significantly lower during OGW in elder group. Results of MSE in vertical direction showed significantly lower values during OGW in younger group. Similar situation was found in medial-lateral direction in elder group. When comparing RMS, significant difference was found only in medial-lateral direction in elder group with lower value during TDW.

Conclusions

The results of this study showed that there are significant differences between overground and treadmill walking. We found that there is an agreement between results computed using different approaches. Both HR and short-term LE indicate that TDW is smoother and more stable, however, that also indicates that walking patterns change during TDW compared to OGW.

Acknowledgements: Supported by a research grant from the Czech Science Foundation (grant no. 15-13980S).

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ASSESSMENT OF POSTURAL STABILITY BASED ON SWAY VECTOR

J.W. Błaszczyk, A. Cichoń, M. Beck, K. Słomka

Jerzy Kukuczka Academy of Physical Education, Katowice, Poland
Email: j.blaszczyk@nencki.gov.pl

Introduction

Postural instability leading to falls and injury is an important and disabling feature of advanced age. Force-plate based static posturography is a simple technique which is frequently used in laboratory and clinical diagnostics. The major disadvantage of this technique is, however, lack of decisive and reliable measures that could be used for assessment of postural instability. Moreover, many parameters that are routinely derived from the COP time series seem to provide very similar information [1, 2]. Numerous methodological deficiencies of static posturography exacerbate reliability of this method. For instance duration of posturographic test, number of trials, data sampling frequency and the COP signal filtering could critically affect the reliability of COP measures [2, 3]. In the search of a reliable method of postural stability assessment COP time series collected recently in our laboratory have been analyzed using set of novel sway measures. Assessment of individual postural control was based on sway vector (SV).

Methods

The SV attributes were computed from the COP data recorded in 30 young women (mean age 23±2) while standing quiet with eyes open and eyes closed:

The length (magnitude) of the SV

$$\overline{V}cop = \frac{Scop}{Ttrial} = L_{SV}$$

The angle (azimuth) of the SV:

$$\varphi = \arctan\frac{S_{AP}}{S_{ML}} = \arctan\frac{V_{AP}}{V_{ML}}$$

Results

Stable standing posture in young healthy subjects determines insensitivity of the control to changes in the input parameter values and its tolerance to perturbations. In young subjects the amplitude of the SV was minimal and only slightly dependent on vision while its azimuth remained at the fixed level of 0.99 radian (51.5 deg). This value of the SV azimuth sets the optimum level of interaction between the AP and the ML controls.

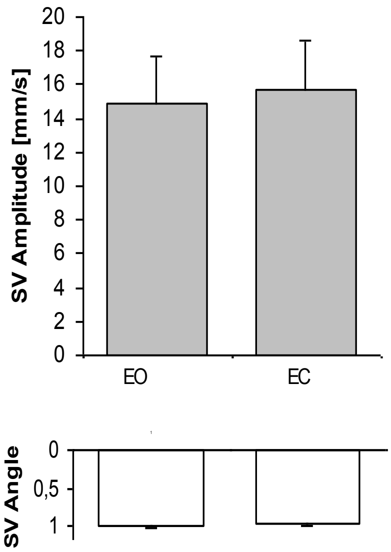

Figure 1 Sway vector (SV) coordinates of the COP stability vectors in young subjects while standing still with eyes open (EO), and eyes closed (EC). The error bars represent standard deviations.

Conclusions

An extension of stability radius notion is our SV, which takes into account both magnitude and direction sway. The SV is a main disturbance during quiet stance, therefore both the magnitude and azimuth of the COP instability vector may serve as measures of postural stability. In this study the instability vector is defined as the smallest destabilizing posture vector in any direction. By definition, a person while standing quiet irrevocably loses balance when his/her COP moves outside limits of stability and the motor control system does not have sufficient time to complete a recovery program. Combination of the SV attributes allow to pinpoint quality of postural stability control. A probability of successful balance recovery in face of perturbation depends on three measures that define the SV: its initial point (the COP reference point), vector magnitude and its azimuth. An increased magnitude of the SV substantially reduces time for balance recovery action and increases probability of fall. The timing of recovery action depends also on direction of perturbation. The latter problem does not exist in young healthy subjects.

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Anticipatory postural adjustments: influence of age, stimulus and parkinsonism

A. Plate, **K. Bötzel**

Dept. of Neurology, Ludwig-Maximilians-Universität München, Germany
Email: kboetzel@med.uni-muenchen.de

Introduction
Anticipatory postural adjustments (APA) prior stepping seem to have impact on step initiation in patients with Parkinson's disease (PD) especially in patients with freezing (FZ). An external stimulus frequently can terminate the freezing episode. We analyzed step initiation of healthy controls (HC) and Parkinsonian patients with regard to changes taking place during aging, changes caused by Parkinsonism and the influence of an external stimulus to trigger the step.

Methods
We examined data from 1594 steps from 84 subjects (HC, PD, PD w. FZ) in 2 conditions (8-10 steps self-initiated, 8-10 steps externally triggered). The path of the center of pressure before the step (APA) was recorded.

Results
Variables of the first step (length, velocity) and APA-measures (APA duration, APA lateral, APA anterior-posterior) showed no significant correlation (Pearson) with age. When a step was elicited by an external command, APAs were significantly larger, faster and shorter in time as with self-initiated steps. Step length had negligible influence on the parameters of the preceding APA. In comparison with the HC group only freezers but not non-freezing PD patients had longer APA duration, reduced APA velocity, and shorter lateral APA excursions. Remarkably, the extent of the APA excursion in anterior-posterior direction was not significantly different between the three groups.

Conclusions
The results of our study show no significant physiological changes of stepping preparation during aging. Surprisingly APA in detail does not seem to be much influenced by the length of the following step. Externally elicited steps are larger (on average 5%) than self-triggered steps and show a clear difference in several APA parameters. Concerning PD patients we found no differences between the anterior-posterior APA excursions in the 3 groups. Only the lateral APA was reduced in the PD groups (significantly only between HC and FZ). PD patients with the freezing phenomenon showed no clear APA difference compared to non-freezing PD patients, from this we conclude that the reduced APA may not be a causal factor for the freezing phenomenon.

RECORDING OF GAIT WITH INERTIAL SENSORS AND INVERSE KINEMATICS

[1]**K. Bötzel**, [1]A. Plate, [2]A. Olivares

[1]Dept. of Neurology, Ludwig-Maximilians-Universität München, Germany
[2]University of Granada, Granada, Spain
Email: kboetzel@med.uni-muenchen.de

Introduction
Inertial sensors are electric circuits which measure acceleration and rotational velocity. This information is needed to determine the 3-D position of a body in space. With the help of those sensors gait can be recorded. Using a 4-segment model for the legs (shank-thigh-thigh-shank) and the stance foot as a pivot, the position of the segments in space can be computed (inverse kinematics).

Methods
We examined twelve healthy young men. Sensors were attached at the thigh as well as at the lower leg on each side. One sensor consisted of one gyroscope und two accelerometers. With the help of an integrated Kalman Filter it was possible to calculate the position of all 4 leg segments in the sagittal plane. Specific pattern of gyroscopic and accelerometric data helped defining moments of terminal contact (toe-off) and initial contact (heel strike). These events were validated by a pressure-sensitive inserted sole. We compared this data with data synchronously obtained from a motion capture system while subjects walked on a treadmill.

Results
Comparison of the time of initial and terminal contact obtained by inertial sensors and pressure sensitive soles resulted in very small deviations within the range of data resolution. The toe-off moment was not at the trough preceding the huge peak of the gyroscope traced during the mid-swing phase. Correlation between segment angles measured with inertial sensors and motion capture system was above $r=0.9$. Correlation between step length measured by these two systems was above $r>0.8$ and could be increased by a calibration of the inertial-sensors system by a defined gait distance.

Conclusions
The method of inverse kinematics allowed for a realistic reconstruction of the gait path and accurate measurements in the sagittal plane. Gait analysis with inertial sensors is less expensive than with conventional methods and allows for the assessment of gait in more natural environments. The actual disadvantage of less precision will be compensated in the near future with better sensors and software. This model may be supplemented by the addition of the pelvic segment which is not yet included.

BODY WEIGHT CONTRIBUTION IN GAIT INITIATION - CROSSING AN OBSTACLE

K. Buckova, J. Lobotkova, Z. Hirjakova, F. Hlavacka

Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia
Email: kristina.buckova@savba.sk

Introduction

Voluntary movements are generally accompanied by postural adjustments. Also prior stepping over an obstacle, shift of center of pressure (CoP) is observed, termed anticipatory postural adjustments (APAs). Postural adjustments are essential because they allow postural disturbance due to the movement. APAs are also associated with the movement control that prevents equilibrium disturbances [1, 2]. Aim of the study was to determine if overweight factor leads to some adjustments necessary to control body inertia and preserve postural equilibrium.

Methods

Twenty overweight and obese adults (7F, mean age 32.7±1.46 yrs, mean height 173.9±2.12 cm, mean BMI 33±1.12 kg.m^{-2}) and 20 normal weight adults (8F, mean age 33.1±1.29 yrs, mean height 170.8±1.99 cm, mean BMI 22.5±0.40 kg.m^{-2}) participated in study, free of any neurological or musculoskeletal disorders. CoP data in anterior-posterior (ap) and medio-lateral (ml) directions were sampled at 100 Hz. A movement analysis system (BTS Smart DX, Italy) with sampling frequency 100 Hz recorded the kinematics of body. Participants were instructed to maintain an upright standing position, with arms along the body and feet parallel at their comfortable stance width. After hearing sound signal, subjects were asked to initiate step with right leg and make few steps at their comfortable speed. Then they were instructed to initiate step by crossing an obstacle with two different heights (low - 2 cm; high - 13 cm). Each trial was repeated 5 times. Assessed variables from CoP signal were: total duration of APAs and amplitude of APAs in both directions (A1ap, A2ap, A3ap, A1ml, A2ml - see Fig. 1A; A3ml was not evaluated because of great variability). From markers data we evaluated parameters for right and left step: time, length, velocity, maximal velocity and time-to-peak maximal velocity.

Results

Overweight subjects had increased amplitudes in lateral direction of preparatory phase of gait initiation (Fig. 1B). We noticed great variability in phase of adjustment (APAs phases according Ruget et al. [3]) corresponding to slow CoP shift onto the supporting foot in obese group. Effect of BMI factor was more evident on parameters of trailing leg.

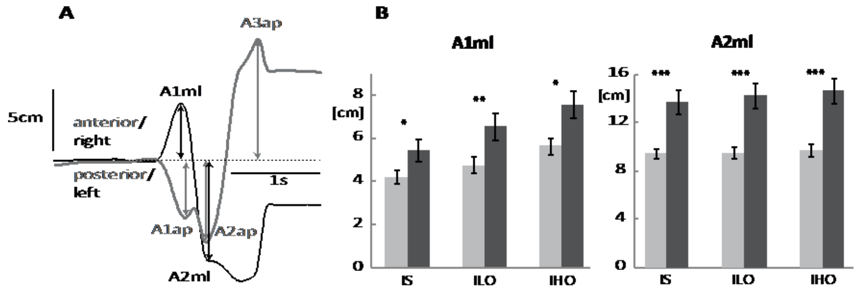

Figure 1 A Amplitude parameters considered in data analysis. **B** Amplitudes in lateral direction A1ml and A2ml of gait initiation without an obstacle (IS), with low obstacle (ILO) and high obstacle (IHO); grey - control group, black - obese group. Mean ± SEM; *p<0.05; **p<0.01; ***p<0.001.

Conclusions

Results showed significantly increased APAs amplitudes in lateral direction in obese group. Training aimed to step initiation in lateral direction could help to improve effectivity of APAs in motor control in overweight and obese subjects.

Acknowledgements: Supported by VEGA grant No. 2/0138/13.

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IDENTIFICATION OF THE PATHOLOGICAL STATE BASED ON MOVEMENT CHARACTERISTICS IN PARKINSON'S DISEASE

[1]**M. Cenciarini**, [2]A. Kuhner, [2]F. Burget, [2]T. Schubert, [1]T. Maier, [1]C. Maurer

[1]Neurology Department, University Medical Center Freiburg, Freiburg, Germany
[2]Institute of Computer Science, University of Freiburg, Freiburg, Germany
Email: massimo.cenciarini@uniklinik-freiburg.de

Introduction

Motor impairments often include reduced mobility, tremor, and rigidity, among others, and they can greatly worsen the quality of life leading to an increased difficulty in moving, a higher risk of falls and fall injuries, as well as suffering from depression in certain circumstances. It is still unclear how the severity of the impairment is linked to the observed motor behavior, but being able to understand how the characteristics of human movement are linked to the pathological state of a patient suffering from a neurological disorder affecting movements is critical for the success of approaches intended for restoring movement functionality. In Parkinson's disease (PD) patients, for example, it is not clear yet, whether the observed motor behavior is the direct result of the disease or of a compensatory response to the debilitating effects of the disease. Maurer et al. have previously suggested that increased sensory noise could explain the motor behavior of PD patients 0. Knowing how the observed motor behavior is linked to the pathological state of patients is a critical and still open problem. In this work we started to address this problem and we chose initially to study PD patients. The experimental protocol included a set of different movement classes and investigate the effects of the pathology across different motor classes and different limbs. We use whole-body motion data to quantify motion behavior and a number of approaches to derive meaningful information about the pathological state of the patients. Our aim is to identify a link between movement characteristics and the severity of the underlying neurological disorder. Identifying this link is important to develop better tools to quantify the pathological state of patients and to evaluate rehabilitative methods using only motion information.

Methods

Eighteen PD patients and 18 healthy subjects participated in this study and completed the testing procedures. Movement tasks included four movement classes: voluntary lean involving postural control, walking straight, complex locomotion tasks, and an everyday-like coordination task (pouring water from a glass into another). The 3D whole-body motion data was measured using the XSens MVN motion capture system. Clinically relevant high-level features were developed such as smoothness, root-mean-square of kinematic measures, and segmental coordination. Moreover, we developed a method that combines features like joint activity, torsion of the trajectory, and time into a classifier for PD patients vs. healthy subjects. A machine learning meta-algorithm (AdaBoost) used these features to compute weak classifiers that are then combined to form a strong classifier. The output can be either a label for the tested dataset (PD vs. healthy) or a continuous variable. Lastly, we developed a motor control strategy approach which comprised of two-steps: 1. complexity reduction by mapping the human motions to a simpler mechanical model, and 2. estimation of adaptive joint weights used by a controller. The joint weights represent the control strategy during motions. All these approaches produce quantitative measures representing the pathological state of patients.

Results

Preliminary results showed that PD patients walked like they "cruised" at a constant speed with very little deviation from the cruising motion; the RMS of the Cartesian acceleration was lower in PD patients in both the straight walking and the hand coordination. Additionally, for the hand-coordination task we found the joint weights to be almost evenly distributed along the arm joints in the PD group, while the proximal joint weights were notably larger than the distal ones in the healthy group 0.

Conclusions

In this work, we have used three different approaches from a more traditional biomechanical measures of motion to more motor control and classifier oriented ones. Preliminary results support our goal that movement related features can be used to quantify the patient's pathological state. These findings can help to evaluate the patient state and evaluate the progress over the course of a therapy or intervention.

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WOODEN WOBBLE BOARD INNOVATION

[1]**M. Cerny**, [1]J. Krohova , [1]M. Smondrk, [2]M. Zadrapova, [2]I. Chwalkova

[1]*VSB – Technical University of Ostrava, Faculty of Electrical Engineering and Computer Science, Department of Cybernetics and Biomedical Engineering, Ostrava, Czech Republic*
[2]*University Hospital in Ostrava, Clinic of Rehabilitation and Physical Medicine, Ostrava, Czech Republic*
Email: martin.cerny@vsb.cz

This paper describes the design and implementation of an interactive rehabilitation system for balance exercises on a wooden wobble board and its implementation into clinical praxis [1].

The proposed rehabilitation system consists of the wireless telemetric wobble board and a computer (Fig. 1a). There is used precise inertial sensor, which allows measurement of the acceleration and orientation in the space. This sensor sends data wirelessly through Bluetooth Low Energy to personal computer. There is done further processing. From technical point of view this system allows very precise continuous measurement of the inclination of the wobble board and also it allows to determine its orientation in the space – the rotation of the wobble board during the exercise.

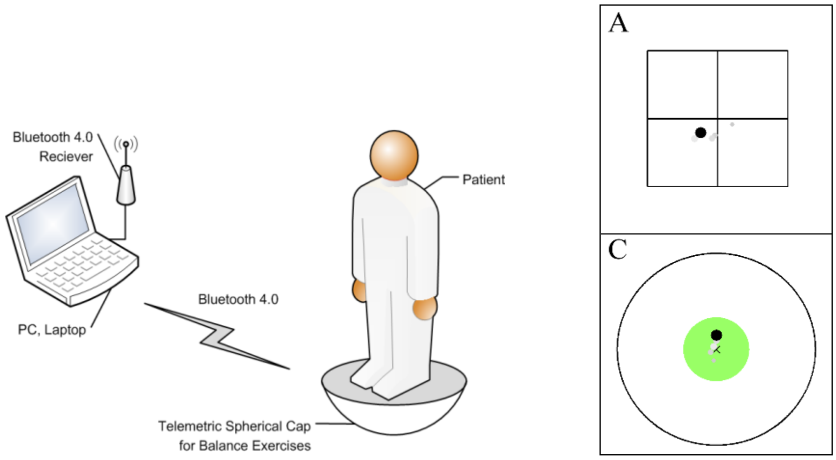

Figure 1 System features (left); rehabilitation programs (right).

This device was primarily designed for the feedback purposes, to motivate patients during their rehabilitation process. There were proposed several rehabilitation programs, which follows the standard use of standard wobble boards in clinical praxis. These shapes represent the object which the patient has to describe (by his own movement) on the wobble board during the rehabilitation. A physiotherapist can adjust the size of selected objects. This value represents the size of the angular deflection in degrees. It can be freely chosen from 10° to 30°. The current patient movement is represented by a two-dimensional representation (Fig. 2bA). The black square represents the selected angular deflection which the patient has to achieve. The black point is the current patient position. It is clear from the name of next rehabilitation program called “Stability” that the patient has to retain stability on the spherical cap (Fig. 2bC). This task has to be performed with a tolerance of 5°, which can be also changed by physiotherapist. The black circle represents the maximum achievable angular deflection. This program also provides values, which can be used for diagnosis of the stability discordances.

Our solution provides better quality of measurement in comparison to other existing solutions. Each exercise is continuously measured so it allows the further analysis of measured values during the rehabilitation process and of course the motivation during the rehabilitation process. The device is under clinical tests in the University hospital now, it is used in rehabilitation after injuries of the lower legs - fractures, soft tissue damage at adults. Also it is used for faulty posture rehabilitations of children.

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WHICH WAY IS UP? VISUAL UNCERTAINTY IN THE ESTIMATION OF GRAVITY

C.J. Dakin, P. Kumar, B.L. Day

University College London (UCL) Institute of Neurology, London, United Kingdom
Email: c.dakin@ucl.ac.uk

Introduction

Identifying which way is up is essential for human posture. To estimate verticality we use visual cues from our environment and graviceptive cues from the somatosensory and vestibular systems. Vestibular graviceptive cues are ambiguous with respect to translational motion, requiring an estimate of head tilt to disambiguate them. Visual motion cues can be used to estimate head tilt, and through this mechanism are believed to indirectly influence our estimate of the orientation of gravity [1]. While it has long been known that visual motion can influence our perception of the orientation of gravity [2], it remains unclear how noise added to visual motion influences the motion-induced bias in our estimation of the orientation of gravity. Here we investigate the influence of noisy visual motion on perception of the orientation of gravity.

Methods

Ten healthy subjects (27±7 yrs) sat head fixed in front of a screen presenting an annulus filled with coloured dots. The annulus of coloured dots could rotate both clockwise and counter-clockwise and was presented at six angular velocities (1, 2, 4, 6, 8, 16 deg/s) and with six levels of coherence (20, 30, 40, 50, 75, 100%). The stimulus was engineered as to keep the net angular velocity of the stimulus constant with varying levels of noise. Participants were required to keep a bar, consisting of a linear sequence of dots and located at the centre of the annulus, parallel to earth vertical by rotating a hand held dial. Low amplitude low frequency angular noise was added to the angular position of the bar to require participants to actively maintain the vertical position of the bar, thus providing a continuous estimate of perceived vertical.

Results

Participant's perception of vertical was significantly influenced by changes in stimulus velocity, as has been previously reported [2]. The addition of visual noise significantly reduced the biasing influence of visual motion on subject's perception of vertical. Together there was a significant interaction between motion coherence and velocity. At low velocities, the biasing effect of visual motion was reduced only by coherence levels below 40%. As motion velocity increased, the reduction in the biasing effect became apparent at higher levels of coherence.

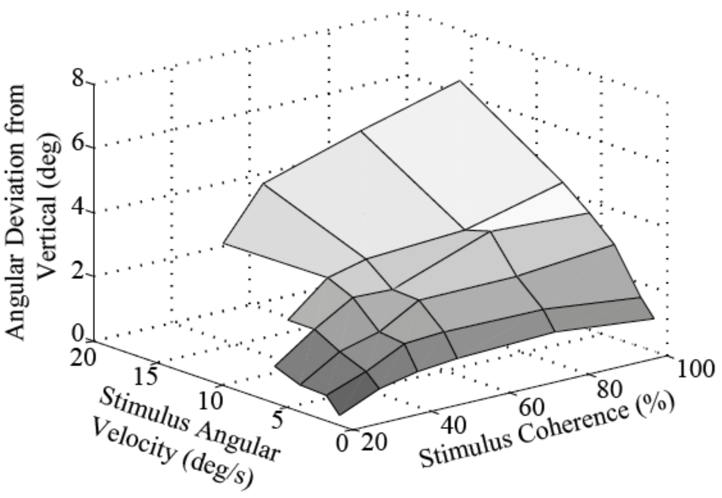

Figure 1 Group means for all velocities and coherence levels. Both the angular velocity of the stimulus and coherence level had a significant influence on magnitude of bias (vertical axis) in participant's perception of vertical. Increasing coherence above 40% had little effect on the magnitude of this bias when velocities were less than 6 deg/s.

Conclusions

Visual scene rotation biases the perception of gravity direction, but the motion coherence between small elements of the scene influences the magnitude of this bias. This influence is non-linearly dependent on the relative amplitude of the noise added to the scene of visual motion.

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Visual rotation influences bipedal stance via self-motion and gravity estimates

B.L. Day, T. Muller, P. Kumar, C.J. Dakin

UCL Institute of Neurology, London, UK
Email: brian.day@ucl.ac.uk

Introduction

One way the visual system helps to maintain upright posture is to identify unintended body movements through visual motion. The source of visual motion, though, is inherently ambiguous – is it due to motion of self or the environment? The brain is susceptible to this ambiguity [1], but not all visual motion is equally ambiguous. This could be because the brain refers to other sensory information that provides alternative noisy estimates of self-motion e.g. vestibular, as well as to memories of prior visual experience [2]. With a prior favouring low body speed in the environment, such a Bayesian framework predicts a decreasing gain of postural response to increasing speed of visual motion [2], a phenomenon that has been found previously with oscillatory stimuli [3]. Here we investigate this in more detail using discrete, rather than oscillatory, constant-velocity rotation stimuli.

Methods

Multi-coloured dots (18 mm dia) were rear-projected onto a large (2.4 x 2.0 m) vertical screen in a darkened room. The dots had a uniform density (300 dots/m^2) and were randomly distributed on a black background. Typically, the scene would rotate clockwise or anticlockwise with ramp and hold angular velocity stimuli of different magnitudes, or remain stationary. In the first experiment, healthy participants (n=10, mean age 23.6±5.0 yrs) attempted to stand stationary on a force plate (Kistler) in front of the screen. Markers were fixed to parts of the body and their movements were recorded in 3D (Coda). The visual scene was set to rotate in the subject's frontal plane about a horizontal axis at ankle height. In the second experiment, subjects (n=10, mean age 27.0±7.0 yrs) were seated with head restraint while they attempted to keep a projected white line vertical using a potentiometer. The line was randomly perturbed by noise while the dot pattern was made to rotate about its centre.

Results

When attempting to stand still, the rotating visual field evoked two sequential postural responses with different properties. The early response was in the direction of visual motion with a latency of 220 ms and, as predicted by the Bayesian model, became smaller with faster stimuli. However, the reduction in response was not explained by a simple modulation of gain. The later response also produced a body displacement in the direction of visual motion with a latency of around 1s, but in contrast became greater with faster stimuli. When seated, the line was deviated away from vertical by the presence of the rotating dot pattern. Like the later postural response, the deviation was in the direction of visual motion and increased in size with faster stimuli.

Conclusions

The results suggest that human bipedal stance is under the control of two independent processes, both of which feed off visual motion. We suggest one is a fast-acting dynamic process that estimates self-motion and acts to minimise it; the other acts to align the long-axis of the body with gravity, the direction of which is distorted by visual scene rotation.

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INVESTIGATION OF POSITION AND FORCES ON THE GAIT CYCLE IN BILATERAL VESTIBULOPATHY PATIENTS

J. Decker, C. Pradhan, R. Schniepp, K. Jahn

Ludwig-Maximillian-University Munich, Munich, Germany
Email: juliandecker.90@gmail.com

Introduction

The vestibular system is essential for orientation, eye coordination and balance. Disorders of the vestibular system occurring in bilateral vestibulopathy patients present various symptoms such as imbalance which is usually compensated with an increase in sensory loading to visual, cognitive and proprioceptive systems. This compensation is often insufficient in cases of increasing demands during turning, different gait speeds and cognitive loading. In this study we investigated relationship of position and forces acting on the semi-circular canals (Reid's plane) during gait tasks and its effects on gait trajectory and stability. Furthermore, we attempted to quantify effects of these forces and positions on gait cycle.

Methods

Ten young healthy subjects (20-40 years), 10 elder healthy subjects (40-60 years), and 10 bilateral vestibulopathy patients (BVP) were recruited for the study. Motion capturing was achieved using Qualisys® with 8 Oqus 100 cameras sampling at 128 Hz. Eleven retro-reflective markers were attached to the head and trunk (4 for the Reid's plane) of each subject. Two synchronized Opal® sensors (tri-axial accelerometers, gyroscopes, magnetometers: Mobility lab® - APDM Devices) were attached to the head and trunk of the subjects sampling at 128 Hz. Subjects were asked to walk along an elongated circle twice (circumference: 12.6 meters) at three different speed rates: preferred, slow and fast, tandem gait, and cognitive dual task (serial subtraction). Additionally, a Timed-up-and-Go test was performed along the long axis. Data analysis was performed using MATLAB® R2015 and GraphPad Prism 6.01 statistics.

Results

First we investigated the "Reid's plane" differences. For preferred, slow and fast walking there was no significant difference between the groups but dual task range movement showed a significant difference for roll (median healthy: 38.21 / BVP: 65.96; $p = 0.044$) and pitch (median healthy: 33.81 / BVP: 49.44; $p = 0.044$). Because of the circular walking route, the yaw interpretation is not possible. These results lead to the assumption that due to concentration on the calculating task the cognitive compensation is reduced and gait instability increases. Focusing on distracted gait we proved further distinctions of the acceleration differences for head and trunk. Finding no significant results for preferred, normal and slow tasks we could confirm a significant difference in x-axis (median healthy: 0.6141 / BVP: 1.571; $p = 0.050$) and y-axis (median healthy: 0.6403 / BVP: 0.9784; $p = 0.045$); not for z-axis. Furthermore, we validated significant differences in median angular velocity of the head during dual task for roll (median healthy: 7.676 / BVP: 9.723; $p = 0.033$) and pitch (median healthy: 7.637 / BVP: 9.731; $p = 0.030$). The higher values arise probably from missing feedback so the movement in head position is recognized later and the correction takes more time. Secondary there could be a remaining function of the vestibular system with a greater difference to the threshold described as 4 degrees in the literature.

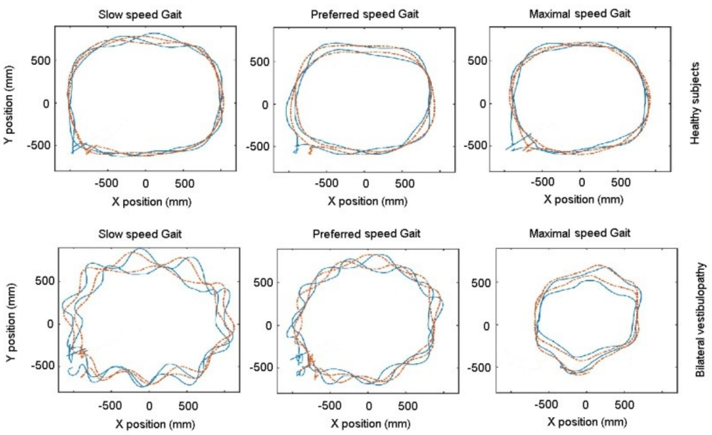

Figure 1 Example motion capturing data for healthy (top) and BVP (bottom) subject.

Conclusions

Our results indicate that for BVP patients there is a higher cognitive load during walking so they walk nearly as good as the healthy subjects during non cognitive load. So for daily clinical gait routine analysis, it is very important to perform cognitive gait tasks to provoke instability gait patterns and diagnose gait pathologies. The analysis we did is a first step showing there are possible parameters to recognize BVP patient. The next step will be the comparison of other pathologies such as cerebellar ataxia to find possibilities to differ diseases. Also the analysis of turnings, especially changes from linear to circular walking, could lead to significant parameter variations in preferred, slow and fast walking which has to be further investigated.

INFLUENCE OF LEVODOPA ON POSTURAL INSTABILITY IN PARKINSON'S DISEASE

I. Di Giulio, R.J. St George, E. Kalliolia, A.L. Peters, P. Limousin, B.L. Day

UCL Institute of Neurology, London, UK
Email: i.digiulio@ucl.ac.uk

Introduction

Postural instability is a common symptom of Parkinson's disease (PD). Levodopa is the gold standard treatment of PD symptoms [1], but its effect on postural instability is unclear [2]. In order to determine whether non-dopaminergic pathways are involved in PD symptoms, the quantification of postural instability response to levodopa is needed. Clinical assessments of postural instability involves the pull test: posterior pull at the shoulder level, with response scored between 0 (normal, recovers with one or two steps) and 4 (very unstable, tends to loose balance spontaneously or with a gentle pull on the shoulders). This test evaluates the number of steps taken, ignoring the other components involved in instability and fails to identify individuals at risk of falling [3]. In the current study, pulls of different force were delivered by motors to measure the components of individuals' postural response: in-place, stepping threshold force, and recovery stepping. Considering all these, we asked: Does levodopa improve postural instability in PD?

Methods

Sixteen PD patients (67±6 yrs, mean±SD) and 16 healthy participants (65±9 yrs) stood symmetrically on two force plates (Kistler) whilst pulls were delivered at their shoulder. Pulls of unpredictable and variable force were applied for 1 s, either forwards or backwards randomly, via strings connected to two motors positioned in front and behind the participant. Participants were instructed to resist the pull. Each session consisted of about 56 pulls. Whole-body kinematics was recorded in 3D (Coda). The PD group were studied OFF and ON levodopa, controls were also tested twice. Each patient was clinically assessed using UPDRS in both sessions. In-place ground reaction force and body sway, stepping thresholds, and step length and number of steps taken were calculated for the two directions in each session, and differences were tested using ANOVA.

Results

The mean UPDRS score improved from 37.9 (±11.7) in the OFF state to 26.4 (±9.4) in the ON state ($p<0.001$). PD patients exerted a lower in-place force in response to pulls compared to controls in both directions ($p<0.05$). Stepping threshold was lower in patients in the forward direction ($p<0.05$). Patients took shorter and more steps in response to pulls compared to controls in the backward direction ($p<0.05$). Levodopa did not improve in-place responses or step length. Only stepping threshold backward and number of steps forward improved when patients were ON levodopa ($p<0.05$).

Conclusions

The benefits of levodopa found here are limited to two quantities in opposite direction, and are generally mild. Overall, the quantities calculated show that most aspects of impaired postural responses are levodopa-resistant. This result suggests that other non-dopaminergic pathways are, or become affected in PD patients and have a key role to play in their postural instability.

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AGE-RELATED CHANGES IN EMG ACTIVITY OF ABDOMINAL MUSCLES OBSERVED DURING MEASUREMENTS OF THE STRENGTH OF PROXIMAL AND DISTAL MUSCLES

[1]**D. Drabarek**, [2]J.W. Błaszczyk, [3]J. Jaszczuk, [3]A. Kędra, [3]J. Zaradkiewicz, [3]R. Golanko, [1]B. Tyszkiewicz-Gromisz

[1]Józef Piłsudski University of Physical Education in Warsaw, Faculty of Tourism and Health in Biała Podlaska, Poland
[2]Nencki Institute of Experimental Biology, Warsaw, Poland
[3]Józef Piłsudski University of Physical Education in Warsaw, Faculty of Physical Education and Sport in Biała Podlaska, Poland
E-mail: d.drabarek@wp.pl

Introduction
In 1998, Massion presented a model of postural control emphasising its antigravity function [1]. Within the model he distinguished two components: control balance and stabilization of the body parts that serve as reference positions for the execution of movement [1]. A higher muscular activity within axial muscles was found to accompany activation of a greater muscle agonist group [2]. In this line of this research we have studied the phenomenon of coactivation of distal muscles involved in a hand grip and the proximal ones responsible for extension of the shoulder joint. The aim of our study was to assess the optimal activity ratio of the *musculus rectus abdominis* (RA) and the *musculus obliquus externus* (OE). The secondary goal was to verify whether the ratio is affected by the impact of ageing.

Methods
Fifty healthy men (25 older adults (OM), mean age 68.3 ± 5.5 yrs and 25 young (YM), mean age 21.2 ± 1.5 yrs) participated in the study. The surface EMG of both RA and OE muscles were recorded while measuring the muscle forces. Their functional interaction was evaluated based on the ratio of max EMG activity of proximal and distal muscles (P/D). The ratio was defined as follow:

$$\text{EMG P/D (RA)} = \frac{\text{level of RA activity during the assessment of proximal force}}{\text{level of RA activity during the assessment of distal force}}$$

$$\text{EMG P/D (OE)} = \frac{\text{level of OE activity during the assessment of proximal force}}{\text{level of OE activity during the assessment of distal force}}$$

Results
The EMG P/D (RA) and the EMG P/D (OE) in the experimental group of young subjects were significantly higher ($p \leq 0.001$) compared with those found in the elderly group. The mean value of the EMG P/D (RA) and the EMG P/D (OE) in YM group remained at the level 2.9 ± 1.2 and 4.36 ± 2.1, while in the OM subjects ranged 1.6 ± 1.9 and 1.66 ± 1.8, respectively.

Conclusions
We found higher ratio of EMG activity in young subjects for both proximal and distal measurements. These findings document a higher core stability in young healthy subjects and also document its progressive decline in the older adults.

Keywords: *posture, core stability, muscle activity, ageing*

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TEST TO RETEST RELIABILITY OF SMART EQUITEST POSTURAL CONTROL AND PERFORMANCE MEASURES IN SARCOPENIC LUNG TRANSPLANT RECIPIENTS

[1]**G. Ebenbichler**, [2]S. Doblhammer, [1]M. Pachner, [3]P. Anner, [1]M. Herceg, [1]K. Kerschan-Schindl, [4]P. Jaksch

[1]Dept. of Physical Medicine & Rehabilitation, Vienna Medical University and General Hospital of Vienna, Vienna, Austria
[2]Lorenz Böhler Trauma Hospital, Vienna
[3]Dept. of Emergency Medicine, Vienna Medical University and General Hospital of Vienna, Vienna, Austria
[4]Dept. of Thoracic Surgery, Vienna Medical University and General Hospital of Vienna, Vienna, Austria
Email: Gerold.Ebenbichler@meduniwien.ac.at

Introduction

Despite removal of ventilatory limitations, patients' exercise capacity and functioning continues to be impaired following lung transplantation (LuTX). This is especially true in the postoperative course, when lung transplant recipients are typically cachectic, sarcopenic and limited in their mobility with an increased risk of falls. Thus, the functional diagnostic assessment and treatment outcome monitoring of impaired postural control and performance seem of major relevance within the rehabilitation process of these patients. This study for the first time sought to examine whether or not different objective measures of postural stability using the SMART EquiTest (NeuroCom) would be reproducible from day to day and sensitive to changes that occur as a result of LuTX rehabilitation.

Methods

A total of 50 lung transplant recipients (median age: 39.7 yrs (range: 20-62), BMI: 19.0±3.9 kg.m^{-2}) underwent all: 1. comprehensive clinical examination using functional assessment tools; 2. quantitative posturographic testing (SMART EquiTest, NeuroCom International, Clackamas, Oregon) that included a) the Sensory Organisation Test (SOT), b) the Motor Control Test (MCT), and c) the Limits of Stability Test (LOS); 3. assessment of posturographic test related personal feelings and fear associated beliefs. Lung transplantation patients were assessed briefly before discharge from the acute hospital stay. All tests were repeated 1 to 3 days after baseline (day 2) and after completion of a comprehensive rehabilitation program (day 3). The main variables of interest were the sum score of the SOT, the average delays derived from the MCTs and the distance of the maximum excursion in the anterior posterior direction (MXE) of the LOS. Reliability was evaluated from the intra-class correlation coefficient (2,1), Bland Altman plots, the standard error of measurement (SEM), and the smallest detectable difference (SDD).

Results

Test to retest reliability was found to be fair for the SOT sum score with an ICC of 0.6, poor for the MCT [ICC(2,1)= 0.2], and excellent for the LOS-MXE variable [ICC(2,1)= 0.86]. At baseline 10.9% of the trials of the SOT resulted in a fall. On the second test day, 1.6 days later, this number decreased to 5.9% and after completion of rehabilitation to 2.2%, respectively. Significant improvements occurred between baseline and the first retest for the SOT composite score; such changes to the better were larger than those observed between the second and third test day. No significant changes in the mean were observed for the MCT or the LOS-MXE. The SEM was 7.1 points for the SOT sum score and 17.1 ms for the MCT, and 10.7 mm for the MXE.

Conclusions

Despite the moderate relative reliability, significant learning effects observed for the SOT conditions limit the clinical application of the SOT for lung transplant patients in rehabilitation practice. For diagnostic purposes the SOT should be administered to LuTX patients only who are virgin to this test. The MCT is neither reliable nor sensitive to changes and therefore is not recommended in lung transplant rehabilitation. Among the three SMART EquiTest postural stability measures, the LOS test was the only one that enabled an excellent level of reliability and an acceptable level of detection of expected changes in postural stability as a result of planned rehabilitation intervention.

Keywords: *posture, lung transplantation, sensorimotor control, sarcopenia, reliability*

MULTI-MODAL ASSESSMENT OF FREEZING OF GAIT AND POSTURAL ADJUSTMENTS IN PATIENTS WITH PARKINSON'S DISEASE

[1]**U.M. Fietzek**, [1]L. Stuhlinger, [2]A. Plate, [2]C. Hamann, [1]A.O. Ceballos-Baumann, [2]K. Bötzel

[1]Dept Neurol and Clin Neurophysiol, Schön Klinik München Schwabing, Munich, Germany
[2]Dept of Neurology, University of Munich, Munich, Germany
Email: ufietzek@schoen-kliniken.de

Introduction

The research into Freezing of gait (FOG) has received substantial input during the last years, and has enhanced our understanding of this characteristic phenomenon of Parkinson's disease (PD). As practically all PD patients develop festination and FOG, we hypothesized that this gait disorder should correlate to other motor aspects of the disease even when patients who do not show typical akinetic freezing are examined. We aimed to (i) corroborate the validity of our clinical FOG assessment and to (ii) explore the role of anticipatory postural adjustments for the prediction of FOG, as postural mechanisms recently were shown to be involved in the pathophysiology of FOG [1].

Methods

We conducted a cross-sectional study at the Schön Klinik München Schwabing and the University of Munich with 28 patients with PD and 18 healthy controls. We assessed the MDS UPDRS score for cognition, non-motor and motor symptoms, and patient self-evaluation of FOG, and we rated a freezing score [2]. Additionally we assessed anticipatory postural adjustments, and performed a walking parcours with turns of varying diameter, that allowed us to examine the patients' ability to perform turns while controlling their step lengths using objective inertial measurements. Recorded data were off-line examined using Matlab algorithms. Clinical data was evaluated using descriptive and correlative analyses.

Results

Patients / healthy controls were mean 65.4 / 62.6 years old, had a disease duration of 9.4 years. They took a mean levodopa equivalent dose of 738 mg. Mean MDS UPDRS motor scores were 36.6. MDS UPDRS non-motor symptom score was mean 10.4 and mean motor symptom score (patient) was 17.9. Mean FOG-Q was 10.8 and mean FOG-score was 7.4. FOG-Q and FOG-S were highly intercorrelated ($r=.71$, $p<.0001$). FOG rating and FOG self-evaluation correlated with motor scores, but not with the non-motor symptoms. Data of neurophysiological assessments will be presented on the poster.

Conclusions

We recorded conclusive data from a small cross-sectional cohort, that demonstrate the validity of our clinical evaluation with good intercorrelations of clinical rating and self-evaluations of FOG, and solid intercorrelations to motor symptoms, however not to non-motor symptoms. Thus, the underlying principle of the FOG rating, to treat festination as a minor form of FOG is validated by this data. The dependency of the gait disorder from postural control measured from anticipatory postural adjustments will be shown in the presentation.

Keywords: *Parkinson's disease, gait, freezing, postural control*

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BI- AND MONOPEDAL POSTURAL CONTROL AFTER ENDURANCE EXERCISES AT DISTINCT INTENSITIES

H. Fischer, R. Beneke

Dept. Medicine, Training & Health Philipps-University, Marburg, Germany
Email: henrike.fischer@uni-marburg.de

Introduction

Endurance exercise can affect postural control. Fatiguing incremental exercise increases postural sway. However, results about effects of different levels of exercise intensity, in particular related to measures of energy metabolism, are inconsistent and rare [1, 2]. Additionally, diversity of methods used to evaluate postural control limits comparability. One leg stance, often used in clinical assessment, makes higher demands on postural control for weight support and vertical alignment of body segments over a reduced base of support. Therefore disturbing effects of fatigue influence postural control more in mono- than in bipedal stance particularly sway in the frontal plane. In bipedal stance, with the widest base of support compared with other stances, and input of all involved sensory systems, even a total compensation seems possible [1]. Therefore, purpose of this study was to investigate effects of cycling exercises at three distinct intensity domains as indicated by metabolic response on postural sway in bipedal as well as monopedal stance.

Methods

19 physically active participants (11 males, 8 females; 24.1±2.3 yrs; 178.9±9.5 cm; 76.0±11.4 kg) performed an exhausting incremental cycle ergometer test (EIT) followed by four 20 min constant load tests at exercise intensities corresponding to 2, 3, 4 and 5 mmol/l blood lactate concentration (BLC) of the incremental test in randomised order. EIT, lowest completed 20 min constant exercise at which the BLC showed no steady-state by increasing until test termination (severe (SE)), and 2 mmol/l intensity test showing a steady-state BLC response after some variability during the initial 10 min (moderate (ME)) were taken for analysis [3]. Postural sway in terms of the Center of Pressure (CoP) was measured immediately before (pre) and 1 min after (post) each exercise for 30 sec in barefooted bipedal (bi) and monopedal (mo) stance. 95% ellipse area (area), average displacement in medio-lateral (ML) and anterior-posterior (AP) plane were analysed.

Results

Area ($p \geq 0.001$, $\eta^2=0.215$), ML ($p \geq 0.001$, $\eta^2=0.285$) and AP ($p \geq 0.01$, $\eta^2=0.058$) show main effects for pre-post, interaction effects of intensity (area $p \geq 0.001$, $\eta^2=0.119$, ML $p \geq 0.001$, $\eta^2=0.143$, AP $p \geq 0.05$, $\eta^2=0.061$), and main effects for stance ($p \geq 0.001$, $\eta^2 \geq 0.531$). Area presents main effect of intensity ($p \geq 0.05$, $\eta^2=0.066$). EIT increases all CoP-parameters in bi (area pre 1.16±0.44 cm^2, post 2.60±1.40 cm^2, $p \geq 0.001$; ML pre 0.13±0.04 cm, post 0.20±0.05 cm, $p \geq 0.001$; AP pre 0.32±0.11 cm, post 0.45±0.15 cm, $p \geq 0.05$) and mo (area pre 6.67±2.22 cm^2, post 9.76±3.57 cm^2, $p \geq 0.001$; ML pre 0.39±0.08 cm, post 0.51±0.11 cm, $p \geq 0.001$; AP pre 0.57±0.11 cm, post 0.66±0.11 cm, $p \geq 0.05$). SE increases area in mo (pre 5.62±1.50 cm^2, post 7.00±2.75 cm^2, $p \geq 0.001$), ML in bi (pre 0.14±0.04 cm, post 0.21±0.10 cm, $p \geq 0.001$) and mo (pre 0.38±0.05 cm, post 0.42±0.09 cm, $p \geq 0.001$). AP is not affected. ME has no effect on any CoP-parameter in bi and mo.

Conclusions

Exhaustive exercise increases postural sway irrespective of base of support. A 20 min moderate exercise has no effect on postural sway. A severe constant exercise of the same duration changes medio-lateral sway in bi- and monopedal stance, whereas area is only affected in one leg stance. Severe, but not moderate endurance exercise seems to challenge postural control in the more demanding monopedal stance with the smaller base of support.

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Learning to control balance: Lessons from rehabilitation and sport

J.S. Frank

Department of Kinesiology, University of Waterloo, Waterloo, Ontario, Canada
Email: frank@uwaterloo.ca

Learning to control balance is an important stage of early human development that continues over a lifetime, declines with aging and can be impaired by injury and disease. When standing, the challenge is to maintain the large mass of the head, arms and trunk (HAT) over the base of support. This challenge increases when walking and running, as the large mass of the HAT must be allowed to move safely beyond the base of support while navigating the environment and moving toward a goal. Sport skills present even greater challenges associated with high precision, force, and/or speed requirements. The challenge that we confront in all of these tasks is coordinating the actions of multiple joints and timing the onset and scaling the magnitude of these actions so as to oppose and/or exploit the destabilizing forces. Destabilizing forces include not only gravity and external forces in the environment, but also intersegment reactive forces arising from movement. I will use examples from research in rehabilitation and sport, including my own research, to demonstrate that balance control learning involves a decrease in redundant degrees of freedom in the coordination of joint actions, a shift from feedback dominant to greater feedforward control and refined scaling of joint actions. My own research has explored balance control learning while participants stood on a continuous motion platform translating at fixed frequency and varying amplitudes for 45 seconds. Participants performed 42 practice trials on day one and returned 24 hours later for a retention and transfer test. Both young [1] and older [2] participants demonstrated learning characterized by a decrease amplitude of HAT center of mass displacement, a transition from ankle dominant to multisegmental control and a shift from phase lag to phase lead control. These changes persisted when participants returned for the retention test and translated to a pattern of platform motion not previously experienced. Learning appeared to reflect a generalized strategy by which participants allowed the lower limbs to "surf" the platform, so as to minimize motion of the large HAT segment.

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INTEGRATION OF DYNAMICAL AUDITORY INFORMATION INTO POSTURAL CONTROL PROCESS

[1]**L. Gandemer**, [1]G. Parseihian, [1]R. Kronland-Martinet, [2]C. Bourdin

[1]LMA, CNRS, UPR 7051, Aix-Marseille Univ, Centrale Marseille, Marseille, France
[2]Aix Marseille Univ, CNRS, ISM UMR 7287, Marseille, France
Email: gandemer@lma.cnrs-mrs.fr

Introduction

Vestibular, proprioceptive and mainly visual information are known to be the principal afferent inputs involved in postural regulation [1]. Surprisingly, only a few studies have addressed the effect of auditory information in postural regulation, and no clear consensus has emerged, because of slightness of effects and different experimental contexts. Here, our goal is to develop a methodology to systematically explore the effects of dynamic auditory information on static balance.

Methods

An innovative 3D sound spatialization system was developed for sound stimuli generation, with 42 loudspeakers equally distributed around the subject. This system allows to create virtual sound sources and to displace it in the whole 3D space. Then, three experiments were conducted on 20 young and healthy standing subjects. Subjects were blindfolded; their body sway was measured with a force platform. The first experiment aimed to investigate the role of a rotating sound source around subjects compared to no sound or a static sound source. Subjects were asked to stand still and focus on sound stimuli. The second experiment addressed the importance of attentional focus in the integration of sound into postural process. Subjects were presented with the same sound stimuli as in experiment 2, but their attention was manipulated in 3 different tasks, where they were asked to: 1 – focus on sound, 2 – focus on their posture and 3 – focus on a secondary mental arithmetic task. In the third experiment, the sound stimuli were designed to compare effect of sound movement evoked by manipulations of its morphology (rendered on one loudspeaker) to real sound source displacement around subject (rendered with sound spatialization).

Results

In the first experiment, body sway of subjects was reduced in presence of a rotating sound stimulus, compared to no sound or static sound conditions [2]. In the second experiment, the same stabilizing effect of rotating sound stimuli was observed but only when subjects' focus was directed on sound stimuli. Then, in the third experiment, subject body sway was greater in conditions where sound movement was evoked by morphology than in real sound source movement conditions.

Conclusions

Data from the three experiments suggest that auditory information can be integrated in postural control process of blindfolded subjects, to reduce their body sway, provided: 1- subjects' attentional focus is on sound, and 2 – sound source is moving around subjects, varying auditory cues. In other situations, sound information does not seem to be crucial as proprioceptive and vestibular modalities are available to manage posture.

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POSTURAL STABILITY OF ELITE MALE AND FEMALE GOLF PLAYERS IN JUNIOR CATEGORY

T. Gryc, F. Zahálka, T. Malý

Charles University, Faculty of Physical Education and Sports, Prague, Czech Republic
Email: gryc.tomas@ftvs.cuni.cz

Introduction

Higher postural stability performance was found in individuals with elite sport experiences compared to individuals without. Postural stability performance was examined through static balance tests by previous researchers and found it useful for patients however not for examining postural stability performance in highly trained individuals. Double narrow stance tests on different surfaces were used to compare static postural stability performance between males and females and did not found significant differences [1]. However, there were not used tests with smaller base of support to find out differences in static postural stability performance between males and females. The purpose of this study was to compare static postural stability performance between junior-aged males and females golf players.

Methods

Thirteen males (mean ± SD: age 17 ± 2,1 years; height 181,5 ± 4,8 cm; weight 77,6 ± 14,8 kg; handicap -1,2 ± 1,7) and twelve females (mean ± SD: age 16,7 ± 2,0 years; height 168,5 ± 3,2 cm; weight 60,8 ± 9,6 kg; handicap -0,4 ± 2,0), who were all right handed elite golf players usually participating in national and international tournaments, participated in this study. Four static postural stability tests were performed on pressure plate FootScan (RScan International, Belgium): double stance feet parallel - eyes open (30 s), double stance feet parallel - eyes closed (30 s) and right and left single leg stance (60 s). We used total travel way (TTW) parameter to evaluate results in each test.

Results

We found significantly higher results in TTW parameter for males than for females in single leg stance test for left (females TTW was 1319 ± 310 mm; males TTW was 1609 ± 351 mm; $t = 2,18$; $p<0,05$) and non-significant for right (females TTW was 1392 ± 477 mm; males TTW was 1501 ± 348 mm; $t = 0,66$; $p>0,05$) lower limb. There were no significant differences between males and females in double narrow stances, both in conditions with eyes open ($t = 0,20$; $p>0,05$) and closed ($t = 0,80$; $p>0,05$).

Conclusions

Left lower limb has stabilizing function during the golf swing of right handed players, especially in final position, where golfer stay only on one leg, just after finishing rotational movement. These findings revealed lower static stability scores (TTW) in single leg stance tests for females than males, but significant for left lower limb only. There were no stability differences between genders in static double stance parallel feet tests. These findings indicate that static stability test with smaller base of support may be more effective discriminator of balance-related performance between male and female elite golf players, especially on lower limb which makes support for movement during the golf swing.

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POSTURAL CONTROL STRATEGY IN NORMAL AND VESTIBULAR-ABLATED STATES STUDIED IN AN ANIMAL MODEL

[1]**C. Haburcakova**, [3]L. Thompson, [1,2]C. Wall, [1,2]D. Merfeld, [1,2]R. Lewis

[1]Jenks Vestibular Physiology Laboratory, Mass. Eye and Ear Infirmary, Boston, United States
[2]Harvard Medical School, Boston, United States
[3]University of the District of Columbia Washington, D.C., United States
Email: Csilla_Haburcakova@meei.harvard.edu

Introduction

Approximately 8 million American adults suffer from some kind of vestibular system impairment. Patients suffering from vestibular dysfunction experience difficulty maintaining their balance and stabilizing their vision. The goal of the study is to characterize postural control strategies in rhesus monkeys in two different vestibular states: normal function and bilateral vestibular hypofunction.

Methods

Two juvenile rhesus monkeys were studied in these experiments, one with mild bilateral vestibular dysfunction and one with severe vestibular dysfunction induced by amynoglycosides administration. Severity of vestibular damage was determined by measuring the vestibulo-ocular reflex (VOR) response. Sway of the trunk in the earth-horizontal roll plane was measured while the animals stood in their normal quadruped posture, before and after vestibular ablation. We measured sway during quiet stance (e.g. no external perturbation) with the support surface configured in 4 ways – condition 1: wide stance with thin (gum) rubber covering the footplates, condition 2: wide stance with foam covering the footplates (which distorts somatosensory inputs), and narrow stance with gum (condition 3) or foam rubber (condition 4) on the footplates. The effect of vestibular ablation on the body sway during quiet stance was further evaluated by utilizing a feedback controller model.

Results

The monkey with mild ablation showed decreased sway of the trunk in all the 4 test conditions after ablation to compare to pre-ablation/normal state. In contrast, the monkey with severe vestibular damages showed an increased sway in three of the four conditions. The model was able to simulate the results in the mildly-ablated monkey by increasing the stiffness parameters of the limbs, suggesting that mild vestibular ablation leads to increased body stiffness which is able to compensate for the vestibular damage. Conversely, further increases in stiffness could not compensate for more severe vestibular damage.

Conclusions

The experimental and model results imply that different compensatory mechanisms are used to improve postural stability depending on the severity of the peripheral vestibular damage. Increased stiffness appears to be employed when damage is mild and appears able to compensate adequately in this situation, while increased stiffness cannot compensate when damage is more severe so other mechanisms must be employed in that situation.

Acknowledgements: This work was funded by a grant from the National Institutes of Health to R.F. Lewis.

AGE-RELATED CHANGES OF BALANCE DURING QUIET STANCE IN ELDERLY FALLERS AND NON-FALLERS

[1]**M. Hamrikova**, [1]Z. Svoboda, [2]E. Zemkova, [1]M. Janura

[1]*Faculty of Physical Culture, Palacky University Olomouc, Olomouc, Czech Republic*
[2]*Faculty of Physical Education and Sports, Comenius University in Bratislava, Bratislava, Slovakia*
Email: hamrikova.marketa@gmail.com

Introduction
Considering the high prevalence of falls in older adults, the identification and description of potential risk factors for falls is required [1]. The aim of the study was to assess the association between age and centre of pressure (CoP) velocity in older adults in the group of fallers and non-fallers.

Methods
Observed group consisted of 144 subjects aged 59–86 years (mean age 71.1 ± 6.7 years). The participants were recruited from thirteen seniors clubs and The University of the Third Age. Postural sways were recorded during 30-second quiet stance using two force platforms AMTI. Participants were tested under four conditions: stance on a firm surface with eyes open and eyes closed and stance on a foam surface with eyes open and eyes closed. Spearman correlation and polynomial regression were used to examine the association between age and CoP velocity (V – total velocity, V_{AP} – velocity in anterior-posterior direction, V_{ML} – velocity in medial-lateral direction) separately for fallers and non-fallers.

Results
Twenty-two of the subjects reported at least one fall and 122 subjects reported no falls in the past three months. Analyses of age-related change of CoP velocity by the polynomial regression showed higher increase of velocities with increasing age in fallers in comparison with non-fallers under conditions with unlimited sensory inputs (Fig. 1), as well as under conditions with limited sensory inputs (eyes closed, foam surface). Under all conditions we found stronger velocity and age correlation in fallers (middle level) than in non-fallers (low level).

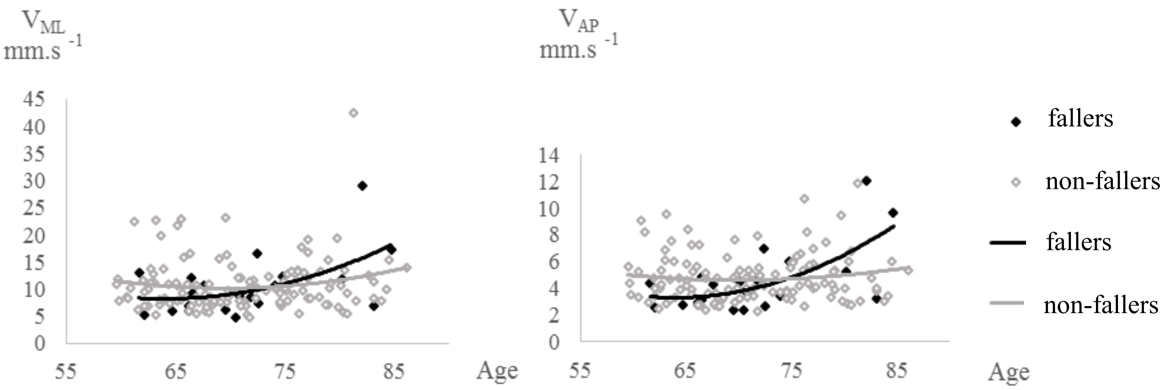

Figure 1 Age-related associations of CoP velocity (V_{AP}, V_{ML}) during stance on a firm surface with eyes open in fallers and non-fallers.

Conclusions
Our results pinpoint the importance of early rehabilitation management, especially in older adults with a fall experience. This may reduce the risk of recurrent falls and improve quality of life in elderly people.

Acknowledgements: The study was supported by a research grant from the Czech Science Foundation (15-13980S) and the grant of the Czech Ministry of Education, Youth and Sports and Slovak Research and Development Agency (SK-CZ-2013-0131, 7AMB14SK073).

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TYPE OF SPORT EXPERTISE BIASES SENSORY INTEGRATION FOR SPATIAL ORIENTATION AND POSTURAL CONTROL

[1]M. Thalassinos, [1]G. Fotiadis, [2]F. Arabatzi, [1]**V. Hatzitaki**

[1]*Phys. Education and Sport Science, Aristotle University, Thessaloniki, Greece*
[2]*Phys. Education and Sport Science, Aristotle University, Serres, Greece*
Email: vaso1@phed.auth.gr

Introduction

Differences exist in the way individuals perceive and use multimodal sensory information for spatial orientation and postural control [1] while athletic experience may influence this process [2]. How sport specific reliance on exteroceptive (i.e. vision) information is associated with sensory integration for controlling posture is not known. To address this question, we compared athletes practicing open and closed skills in a) a visual field dependence task and b) a balance task which evoked sensorial reweighing. We hypothesized that athletes practicing open skills would demonstrate greater visual field depedence which negatively affects their ability to weight sensory information for controlling posture.

Methods

Ten university athletes (21-24 yrs, 10 yrs of practice) practicing open skill dominated sports (soccer and basketball) and 13 athletes (21-24 yrs, 10 yrs of practice) from closed skill dominated sports or activities (dance and gymnastics) performed: a) the Rod and Frame Test and b) a 100 s standing task during which vision and proprioception were disrupted in 20 s blocks: 1. Eyes Open (EO), 2. Eyes Closed (EC), 3. Eyes Closed - Achilles Tendon Vibration (80 Hz, 3 mm, EC_TV), 4. Eyes Open - Tendon Vibration (EO_TV) and 5. Eyes Open (EO). Postural performance was quantified in the disparity (SD) of the Centre of Pressure (COP) and the integrated EMG activity of the ankle muscles calculated over each 20 s sensory condition.

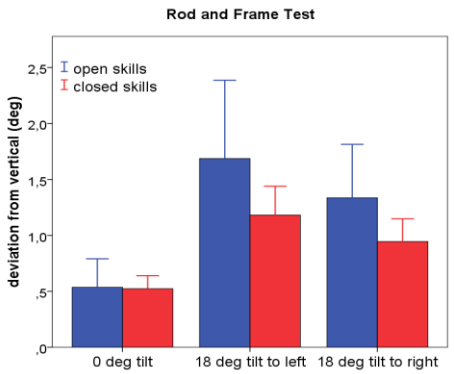

Figure 1 Absolute error (°) for open (blue) and closed (red) skill athletes across the 3 frame tilt conditions. Group mean ± st. error.

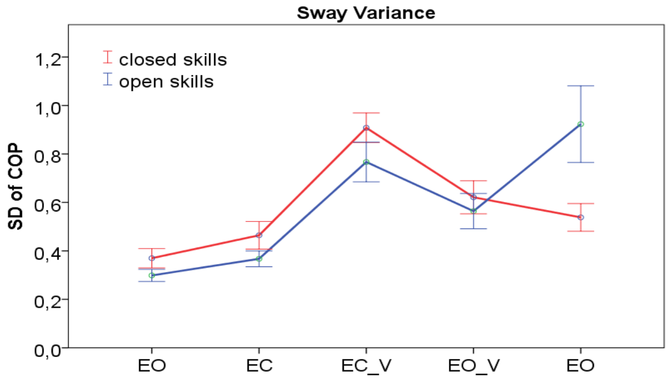

Figure 2 SD of COP for open (blue) and closed (red) skill athletes across sensory conditions. Group mean ± st. error.

Results

Athletes practicing open skill sports had significantly greater visual field dependence compared to athletes practicing closed skills [Fig.1, $F_{(1,21)}=4.5$, $p<.05$]. Sway variability increased with TV(EC_V) and decreased when vision was re-inserted (EO_V) similarly in both groups [Fig.2, $F_{(4,84)}=24.45$, $p<.001$]. However, open skill athletes further increased SD of COP when proprioception was re-inserted [EO, $F_{(1,21)}=9.49$, $p<.01$].

Conclusions

Increased visual field dependence impairs the ability of athletes practicing open skills to properly reweigh proprioceptive information leading to increased instability at the offset of tendon vibration. Practical implications of this research point to the critical role of proprioceptively driven balance training for athletes practicing open-skill dominated sports.

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MULTI-MODAL APPROACH TO REDUCING FALL RISK: MOTOR-COGNITIVE INTERACTIONS AND THEIR POTENTIAL PLASTICITY

J.M. Hausdorff

Center for the Study of Movement, Cognition, and Mobility,
Department of Neurology, Tel Aviv Sourasky Medical Center, Israel
Sagol School of Neuroscience, and Sackler Faculty of Medicine, Tel Aviv University, Israel
Email: jhausdor@tlvmc.gov.il

In this presentation, I will describe the interesting, under-appreciated links between falls, gait and cognition and the implications these links have for reducing fall risk.

Falls are ubiquitous among older adults and patients with common neurological diseases. Approximately 30% of community-dwelling adults over the age of 65 fall at least once a year. In persons with neurological disease like Parkinson's disease (PD), mild cognitive impairment (MCI) or dementia, falls are even more frequent with annual incidence rising to 60–80%. The consequences of these falls may be severe, leading to institutionalization, loss of functional independence, disability, fear of falling, depression and social isolation.

Fall risk is often multi-factorial. Past work has shown that changes in muscle strength and power, sensory function, balance and gait may all contribute to fall risk. Nonetheless, multi-factorial interventions that attempt to target these fall risk factors have shown only limited success at reducing the risk of falls. We suggest that one reason for this sub-optimal response to therapeutic attempts at reducing fall risk stems from the fact that a key component has been missing from these types of interventions: the head.

Indeed, the control of posture and gait was once considered to be an automatic task that requires minimal higher-level cognitive input. This presentation will briefly review the evidence that links cognitive function to gait and fall risk in healthy older adults and in patients with neurodegenerative disease and explain why safe ambulation depends on executive function and attention. Building on those insights, we describe findings that demonstrate the potential of novel therapies for enhancing mobility and cognition and for reducing fall risk. A final example introduces an integrated approach that combines treadmill training with virtual reality and an exciting new imaging tool, functional near infra-red spectroscopy, fNIRS. This will enable us to illustrate how a multi-modal, motor-cognitive intervention may promote beneficial neural plasticity in frontal lobe activation during complex walking conditions to enhance cognition, gait and safe ambulation. Attention to the role of the cortical control of posture and gait may lead to a more complete understanding of these "motor" tasks and help to reduce the debilitating effects of falls in older adults.

BREATHING CHANGES ASSOCIATED WITH POSTURAL IMPROVEMENT DUE TO VISUAL BIOFEEDBACK

[1]**Z. Hirjaková**, [2]K. Neumannová, [1]J. Lobotková, [1]K. Bučková, [1]F. Hlavačka

[1]*Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia*
[2]*Department of Natural Sciences in Kinanthropology, Faculty of Physical Culture, Palacky University, Olomouc, Czech Republic*
Email: zuzana.hirjakova@savba.sk

Introduction

In standing posture, respiratory movements constitute an internal periodic perturbation to body balance. Spontaneous breathing influences the body's center-of-mass by altering trunk volume [1]. However, respiration is a source of highly predictable perturbation, postural control foresee its effect and compensate for it [2]. Yet, an interesting question is emerging here: May be the involuntary physiological function as breathing altered in order to achieve better balance control? The aim of the study was to find the relation between the centre of pressure (CoP) displacement and respiratory chest movement in condition with additional visual information.

Methods

Fifty young healthy subjects (24 men, mean age 28.0±3.7, mean BMI 22.2±2.8 $kg.m^{-2}$) were tested in control condition: stance with eyes open and foam surface (FEO); and in the condition with visual biofeedback on foam surface (VF). Amplitudes of CoP in anterior-posterior and medial-lateral directions were measured by the force platform. Breathing amplitudes were recorded and calculated from two pairs of accelerometers (Xsens, Enschede, The Netherlands) attached on upper chest (UCB – upper chest breathing) and on lower chest (LCB – lower chest breathing). Subjects were randomly divided into two groups: one group of 25 subjects was tested also with spirometry at the same time.

Results

The results showed that breathing amplitudes significantly decreased and frequency of LCB cycles significantly increased during VF condition comparing to control condition in both groups. With reducing amplitudes of CoP displacement in both directions, the breathing was reduced accordingly in both groups. There were no significant differences between the control group and the group wearing the spirometry mask. Additional spirometry measurements confirmed decreased tidal volume during VF condition and verified that breathing movements recorded by the pair of accelerometers located on lower chest were reliable.

Conclusions

Results showed that the reduction of breathing movements with increase of breathing frequency is an involuntary strategy to help balance improvement during challenging condition with additional visual information. Along with the reduction of postural sway, breathing movements were suppressed in order to achieve better performance in biofeedback task. The study also proved that abdominal breathing movements could be reliably recorded by couple of accelerometers attached to the proper locations on lateral sides of lower chest.

Keywords: *posture, breathing, visual biofeedback, centre of pressure, accelerometry, spirometry*

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ANTICIPATORY POSTURAL ADJUSTMENTS AFFECTED BY THE SENSORY MANIPULATION IN YOUNG AND ELDERLY SUBJECTS

J. Lobotková, K. Bučková, Z. Hirjaková, **F. Hlavačka**

Laboratory of Motor Control, Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia
Email: jana.lobotkova@savba.sk

Introduction

The ability to maintain balance deteriorates with advancing age since sensory and motor resources required for postural stability and orientation decline with ageing [1]. Balance and gait impairments characteristic for older adults predict the risk of falling, and are important contributors to reduced quality of life [2]. An understanding of age-related changes in motor behaviour is important when considering the design of training programs for fall-prevention in the elderly. The aim of this study was to examine how the manipulation of the sensory inputs before step initiation affects the anticipatory postural adjustments (APAs) in healthy young and elderly subjects.

Methods

Twenty-two young adults (13 F, mean age 29.0±3.4 yrs) and 22 healthy elderly subjects (13 F, mean age 73.7±5.6 yrs) participated in the study. Standing on the embedded force platform, they were instructed to initiate a gait with the right leg after hearing an auditory signal, and make 5-7 steps forward. During the initial quite stance, bilateral tendon vibration (80 Hz, 1 mm) was applied either to *m. tibialis anterior* (bTA) or *m. triceps surae* (bTS) for period 5 s. The end of vibratory stimulation and auditory signal were set at the same instant. Visual perception was modified by closing the eyes before the step initiation and executing first three or four steps with eyes closed. As a control trial, gait was initiated without any previous sensory manipulation. Each of 6 different conditions was repeated 5 times, trials were randomized. Trunk motion was recorded by two MTx inertial sensors (Xsens, Enschede, The Netherlands) attached to the sternum (ST) and lower back (L5). APAs were evaluated by its duration (D), max. amplitude (Amax) of the centre of pressure (CoP) displacement in anterior-posterior (AP) and medial-lateral (ML) directions, max. velocity (Vmax) of CoP in both directions, and acceleration of upper and lower trunk in both directions.

Results

We found significant relationship between APAs and somatosensory afferentation from lower leg muscles, particularly in young subjects. Tilt of body vertical induced by vibration before the step initiation resulted in significant changes of APAs duration, max. amplitude and max. velocity of CoP in both AP and ML directions. Moreover, the acceleration of upper trunk changed significantly in both directions too, lower trunk only in ML plane, and these changes were observed in bTS condition. Contrary, we did not find any significant effect of vibration on APAs duration, max. amplitude either max. velocity of CoP in AP direction in the group of elderly. Only significant increase of Amax and Vmax in ML direction was observed during gait initiation with eyes open in bTA. Changes of trunk acceleration after vibratory stimulation were also rare in seniors compared to juniors.

Conclusions

Young adults shown very sensitive adaptation of APAs to modified somatosensory inputs from lower leg muscles. The effect of proprioception on gait initiation decreased with age. Insufficiency of significant changes in APAs after vibratory stimulation in older adults suggest reduced proprioceptive sensitivity of lower leg muscles which along with impaired sensorimotor integration can contribute to postural instability and fall risk. Thus rehabilitation in elderly should be targeted to improvement of balance control as well as muscle sensitivity and muscle strength during the transient event from standing to walking, particularly to preparatory phase including anticipatory postural adjustments.

Acknowledgements: This work was supported by VEGA grants No. 2/0138/13 and 1/0373/14.

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PROCESSING TIME OF ADDITION OR WITHDRAWAL OF SINGLE OR COMBINED BALANCE-STABILIZING HAPTIC AND VISUAL INFORMATION

[1,2]**J.L. Honeine**, [1]O. Crisafulli, [2]S. Sozzi, [1,2]M. Schieppati

[1]*University of Pavia, Pavia, Italy*
[2]*Fondazione Salvatore Maugeri I.R.C.S.S., Pavia, Italy*
Email: jeanlouis.honeine@unipv.it

Introduction

Maintaining equilibrium during upright stance requires continuous integration and reweighting of vestibular, proprioceptive, visual and haptic inputs [1]. One way of investigating sensorimotor integration is to measure the time necessary for the brain to integrate new sensory information and make use of it for sway regulation [2]. In this study, we investigated the integration time of haptic and visual input and their interaction during stance stabilization. We hypothesized that the concurrent addition of both sensory inputs would facilitate the integration process resulting in a reduction in both latency to the initial change in sway and time course to reach the new steady-state.

Methods

Eleven subjects (mean age 27.4 ± 5.4 yrs; 7 F) performed four tandem-stance conditions (60 trials each). Vision (V), touch (T), (V&T) were passively added and withdrawn; (V⇔T) vision was replaced with touch and vice versa. Body sway, tibialis anterior, peroneus longus and soleus activity were measured.

Results

Following addition or withdrawal of vision or touch, an integration time-period elapsed before changes in sway (decreasing with added vision and/or touch and vice versa) were observed. Thereafter, sway varied exponentially to a new steady-state while reweighting occurred. Latencies of sway changes ranged from 0.6 to 1.4 s (Fig. 1). They were preceded by changes in muscle activity by around 110 ms. Latencies following addition were longer for touch than vision. Addition of vision and touch simultaneously shortened the latencies with respect to vision or touch separately, suggesting cooperation between sensory modalities. Latencies following withdrawal of vision and/or touch were shorter than following addition. When vision and touch were exchanged, adding one modality did not interfere with withdrawal of the other, suggesting that incorporation of withdrawal and addition were performed in parallel. The time constants of the reweighting process were shorter on withdrawal than addition and were similar for vision and touch alone. However, the time to reach steady-state was reduced significantly when both touch and vision were added concurrently.

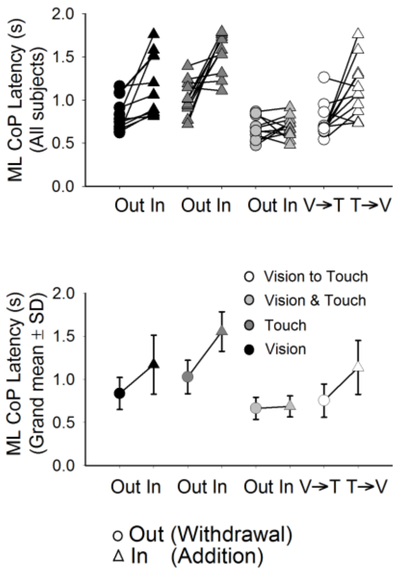

Figure 1 Latencies following addition and withdrawal of vision and/or touch.

Conclusions

The effects of different posture-stabilizing sensory modalities illustrate the operation of a central process that integrates and fuses modalities for accurate balance control. This study is the first to show the facilitatory interaction of visual and haptic inputs in integration and reweighting of stance-stabilizing input following withdrawal or addition.

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GAIT INITIATION: THE FRONTAL-PLANE CONTROL

[1]**J.L. Honeine**, [3]M.C. Do, [1,2]M. Schieppati

[1]*University of Pavia, Pavia, Italy*
[2]*Fondazione Salvatore Maugeri I.R.C.S.S., Pavia, Italy*
[3]*University Paris-Sud, Orsay, France*
Email: jeanlouis.honeine@unipv.it

Introduction

Gait initiation (GI) is a precise task, in which centre of pressure (CoP) and centre of mass (CoM) are tightly controlled. The distance created between CoM and CoP (CoM-CoP gap) in the sagittal plane produces a disequilibrium torque driven by gravity, responsible for accelerating the body forward [1]. This torque is braked by the triceps surae activity [2]. We hypothesised that a similar process occurs in the frontal plane, and that selected muscles are put into action for the medio-lateral (ML) control of GI.

Methods

Twelve healthy young adults (mean age 29.1 ± 4.3 yrs; 6 F) participated in the experiment. They performed gait initiation in three conditions composed of 10 trials each, starting from: 1) normal step-width at normal velocity; 2) normal step-width at fast velocity; 3) large step-width at normal velocity. Two force platforms, appropriately located, measured CoP position during the stance phase of the first and second step. Twenty-three markers allowed calculation of CoM position in space. EMG activity of soleus, tibialis anterior, peroneus longus, abductor magnus and tensor fasciae latae (TFL) on both sides were measured.

Results

Prior to heel-off, CoP briefly moved under the future swing leg, in order to allow CoM displacement towards the stance leg. The amplitude of the CoP shift was greater for large with respect to normal step-width condition. Following heel-off, CoP was moved under the stance foot. Instantaneous ML velocity at the instant of foot-contact was lower during the fast condition with respect to the normal and large condition. ML velocity of CoM in all conditions was entirely generated by the shear force that is caused by the disequilibrium torque (Fig. 1). Hence, by modulating the CoM-CoP gap the central nervous system can control the ML velocity of CoM. TFL of the stance leg was more active in the fast condition (when the gap is smallest).

Conclusions

In gait initiation, the medio-lateral ground reaction force is generated by the disequilibrium torque. Hence, by controlling the distance between CoM and CoP the central nervous system is capable of controlling CoM displacement. The TFL of the stance leg plays a role in fine tuning the gap by means of counteracting the lateral displacement of CoM.

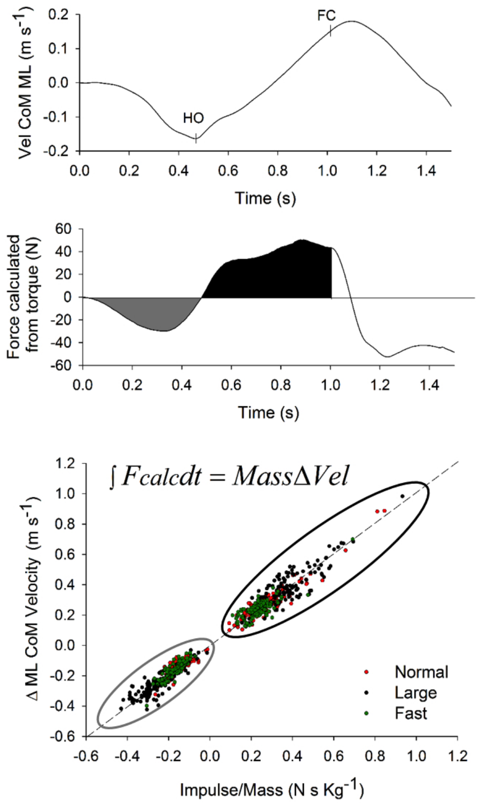

Figure 1 Distribution of the impulse calculated from the torque (abscissa) and ML velocity.

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COGNITIVE CONTRIBUTIONS TO COUPLING POSTURE AND GAIT

F.B. Horak

Department of Neurology, Oregon Health & Science University, Portland, USA
Email: horakf@ohsu.edu

Functional mobility requires a tight coupling between neural control of postural equilibrium and stepping. Freezing of gait (FoG) in patients with Parkinson's disease (PD) provides a good example of disrupted posture-gait coupling. We propose that FoG results from failure to inhibit anticipatory postural adjustments and failure to release inhibition of the stepping program. For example, voluntary step initiation in the elderly and people with PD induces freezing-like delayed step initiation with multiple anticipatory postural adjustments in complex reaction time conditions.

Our working hypothesis is that FoG is due to abnormal frontal lobe executive inhibition function critical for coupling posture and gait. We provide evidence that : 1) FoG is associated with specific types of executive function deficits involving response inhibition and 2) FoG is associated with disrupted structural and functional connectivity of the right hyperdirect pathway between preSMA, STN, PPN and other parts of the locomotor circuit, which is also the executive inhibition (conflict resolution) circuit. In fact, functional connectivity between SMA and PPN is related to an objective FoG ratio from inertial sensors on the lower legs. SMA-PPN connectivity is also related to dual-task interference on stride length, especially in those with FoG.

Recently, we are investigating the efficacy of a novel group exercise intervention involving agility training with cognitive challenges (inhibition, dual-tasking, and set switching) on mobility, FoG, cognition, and brain connectivity.

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INFERRING QUALITY AND QUANTITY OF PHYSICAL ACTIVITY PERFORMED AT HOME FROM POSTURAL SWAY MEASURES: MORE THAN MEETS THE EYE?

[1]S. Mellone, [2]M. Colpo, [2]S. Bandinelli, [1]**L. Chiari**

[1]Department of Electrical, Electronic, and Information Engineering, University of Bologna, Bologna, Italy
[2]Laboratory of Clinical Epidemiology, Azienda Sanitaria di Firenze, Firenze, Italy
Email: lorenzo.chiari@unibo.it

Introduction

Smartphones (SPs) and wearable embedded systems are ever more popular as ecological probes to learn about the ageing process or unobtrusive aids to support seniors in their daily life activities and prevent falls and frailty. As an example, SPs can now be used for instrumenting functional tests and for long-term monitoring of physical activity at home, hence providing instrumental measures of the motor and balance performance both in controlled environments and "in the wild". The broad potentials of SPs along these lines was assessed within the FARSEEING-InChianti study (farseeingresearch.eu; inchiantistudy.net), a cohort study of factors contributing to loss of mobility in late life. In this study we aimed to investigate the association, if any, between quiet stance measures, assessed in the lab, and features derived from daily living activities of elderly people.

Methods

The study included 170 elderly subjects (80±6.5 years old, 96 females). An Android application was designed to get the control of sensors embedded in the SP and to implement a modified Romberg test: subjects stood, in the lab, with feet shoulder-width apart for 30 seconds with eyes closed while wearing the SP on the lower back by means of an elastic belt. Sway measures extracted from the signals were related to the Center of Mass (CoM) displacement in analogy to those computed from the Center of Pressure [1]. A second, custom Android application aimed at the long-term monitoring of physical activity was designed and installed on the same SP. This was used to monitor subjects at home for at least 5 days (up to 9). A set of sensor-based features was extracted from the signals including the % of sedentary, active, and walking time, duration of the activities, and mean gait and turning characteristics. Multiple Linear Regression models confounded by age, gender, and BMI were used for investigating the association between postural sway measures and the outcomes of the monitoring at home.

Results

High mean velocity of the CoM displacement in Antero-Posterior (AP) direction was associated to increased sedentary time and to decreased walking time (R^2=0.158-0.166). High mean velocity of the CoM displacement in AP and Medio-Lateral (ML) directions and high values of the AP and ML sway path were associated to an increased gait variability (R^2=0.138-0.181), a lower gait smoothness (R^2=0.137-0.198), and slower (R^2=0.141-0.15) and smaller (R^2=0.081) changes of direction while walking. High values of AP sway RMS were also associated to a reduced number of steps (R^2=0.104) and to shorter walking periods (R^2=0.107).

Conclusions

This study provides novel evidence on the influence of the effectiveness of balance control, quantified by postural sway measures recorded in the lab, on the daily activities of community-dwelling older persons. Such results support the hypothesis that balance performance in quiet stance may find significant correlates in mobility patterns at home.

Keywords: *quiet standing, wearable inertial sensors, activity monitoring*

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IDENTIFICATION OF AN INDIVIDUAL BY FUNCTIONAL ANALYSING OF HUMAN GAIT

[1]**M. Chvosteková**, [1]E. Fišerová, [2]K. Sulovská

[1]Palacký University Olomouc, Faculty of Science, Department of Mathematical Analysis and Mathematical Applications, Olomouc, Czech Republic
[2]Tomas Bata University Zlín, Faculty of Applied Informatics, Department of Electronics and Measurement, Zlín, Czech Republic
Email: martina.chvostekova@upol.cz

Introduction
Functional data analysis is an emerging statistical analysis technique in human movement research, see e.g. [1]. In this approach the real-time series data are treated as a function what implies that all of the information is retained in the data and it is not discarded by summarizing the data by single numbers, e.g. means, standard deviations. It is assumed that the human gait is generated by some underlying function and the discrete time-ordered measurements for an individual obtained by the video recording of the gait are a snapshot of that function. In our contribution we consider an ANOVA test for functional data to study whether the identification of an individual via analysing the human gait is possible or not. The results of study performed for the data set contained the gait observations from 12 participants under different conditions are presented.

Methods
There were selected 20 the best visible anatomical landmarks to obtain marker trajectories in milimeters. The measurements utilized by the Vicon MX T020 system were done for 7 different situations and for each individual was 10 times repeated measurement under the same conditions. The observed values from a marker for ith individual in mth repetition can be expressed as

$$y_{im}(t_j) = \sum_{k=1}^{K} c_{imk}\, \Phi_k(t_j) + \varepsilon_{im}(t_j), i = 1,2,\dots,12, m = 1,2,\dots,10, j = 1,2,\dots, n_{im}$$

where t_j denotes the *j*th time point, n_{im} indicates the number of values measured for *i*th individual in *m*th repetition, and $\varepsilon_{im}(t_j)$ denotes the measurement error. The observations are written as linear combinations of *K* basis functions $\{\Phi_1, \Phi_2, \dots, \Phi_K\}$, we consider B-spline basis functions; and plus some noise. To fit the data the coefficients c_{imk} were estimated by data smoothing with a roughness penalty. The difference in movement patterns between individuals were determined by the F_{max} test via bootstrapping, see [2, 3].

Results
The markers THI (thigh – lower later 1/3rd surface of the thigh), WBR (wrist bar little finger side), ASI (anterior superior iliac spine points) were detected as significant for human gait recognition.

Conclusions
Our research was focused on recognition an individual or a group by analysing the position change in ideal camera surveillance system. The statistical significance difference of gait patterns under different conditions was tested by employing the functional data analysis techniques. The results of 20 markers for individuals and according to gender are presented.

Keywords: *human gait, functional data, ANOVA test for functional data*

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SELECTION OF REHABILITATION EXERCISES FOR THE VIRTUAL PHYSIOTHERAPIST SYSTEM BASED ON INERTIAL SENSORS

[1]**H. Josiński**, [1]A. Świtoński, [2]R. Mucha, [3]A. Szczęsna

[1]Polish-Japanese Institute of Information Technology, Bytom, Poland
[2]Medical University of Silesia, Bytom, Poland
[3]Silesian University of Technology, Gliwice, Poland
Email: hjosinski@pjwstk.edu.pl

Introduction

This report relates to the initial phase of the project which aims to create virtual physiotherapy system based on inertial measurement units (IMU). Single inertial sensor is made of gyroscope, accelerometer and magnetometer. The sensors are part of the Human Motion Suit (HMS) [1] – a hardware and software system for indoor and outdoor motion capture measurements. The concept of virtual rehabilitation aims for remote automatic control of rehabilitation exercises based on comparison of recording of patient's completion of given exercise with a pattern recording. At the moment, our research aims to propose and verify diagnostic correctness of quality assessment of completion of rehabilitation exercises based on motion data obtained from the IMU sensors.

Methods

We carried out initial experiments during which with the help of the motion capture system we registered the rehabilitation exercises course. The exercises were performed by both patients and control group – we compared the results. Simultaneous video recording by two cameras with the mutually perpendicular axes provided the referential information. We took into account following types of disorders: Parkinson's disease, stroke, coxarthrosis, and osteoarthritis of the spine.

Results

Exercises were chosen based on the category of the disorder [2], they are presented in Table 1 along with allocation of the sensors. The output data of the sensors is taken into consideration during assessment of the quality of performance of the exercise.

Table 1 *Disorders types, exercises and allocation of the relevant IMU sensors.*

Type of disorder	Rehabilitation exercise	Allocation of IMU sensors
Parkinson's disease	Frankel's exercise for coordination	Cingulum membri inferioris, membris inferioris
Stroke	Assisted exercises	Regio deltoidea, regio scapularis, regio cubitalis anterior, regio carpalis anterior
Coxarthrosis	Pelvic girdle exercises	Regio lumbalis, region glutealis, regio trochanter major, spina iliaca anterior superior
Osteoarthritis of the spine	Low back pain exercises	Regio lumbalis, cingulum membri inferioris

Conclusions

We found the possibility of detection of differences in the quality of performed exercises based on motion capture recordings. It opens the possibility of correct assessment of exercises performed in the suit without the necessity of leaving the house – it would enable to shorten the time of waiting for rehabilitation.

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AGE AND GENDER RELATED NEUROMUSCULAR AND KINEMATIC PATTERN DURING TRUNK FLEXION-EXTENSION IN CHRONIC LOW BACK PAIN PATIENTS

[1]**T. Kienbacher**, [1]E. Fehrmann, [1]R. Habenicht, [1,4]D. Koller, [1,4]C. Oeffel, [1,3,4]J. Kollmitzer, [1,5]P. Mair, [1,2]G. Ebenbichler

[1]Karl-Landsteiner-Institute for outpatient rehabilitation research, Vienna, Austria
[2]Department of PMR, Medical University of Vienna, Austria
[3]Technical school of engineering, Vienna, Austria
[4]University of biomedical engineering, Vienna, Austria
[5]Department of psychology, Harvard University, Cambridge, MA, USA
Email: kienbacher@rehabzentrum.at

Introduction
The root mean square surface electromyographic activity of lumbar extensor muscles during dynamic trunk flexion and extension from a standing position and the task specific ranges of motion have repeatedly been recommended to objectively assess muscle function in chronic low back pain patients. However, literature in older patients is sparse. This cross sectional study sought to examine these age (<40 versus 40 to 60 versus >60 years) and sex related differences during a standardized trunk flexion-extension task.

Methods
A total of 216 patients [62 older (33 females, 60-90 years), 84 middle-aged (44 females, 40-60 years), and 70 younger (34 females, 18-40 years)] performed trunk flexion-extension testing by holding static positions at standing, half, and full trunk flexion. The lumbar extensor muscle activity and the ranges of motion at the hip and lumbar spine were recorded and calculated using 3d-accelerometers overlying L5 (multifidus) and T4 (semispinalis thoracis) levels. Permutation ANOVA with bootstrapped confidence intervals were performed to examine for age and gender related differences of test results. Secondary analysis employed ridge regressions investigating the impact of physical-functional and psychological variables on the half flexion relaxation ratio (i.e. muscle activity at the half divided by that in maximum flexion position).

Results
Measurements revealed highest muscle activity at standing in the oldest and the female group. Patients over 60 years showed lowest activity changes from standing to the half (increments) and from half to the maximum flexion position (decrements) leading to significantly lower half flexion relaxation ratio compared to the youngest patients. These oldest patients demonstrated the highest hip and lowest lumbar task specific ranges of motion. Females had higher hip and gross trunk ranges of motion compared to males. Total lumbar range of motion and the muscle activity at standing had significant impact to the half flexion relaxation ratio.

Conclusions
This standardized trunk flexion-extension task involving isometric test positions is feasible for older patients and those younger. Gender and aging significantly affect the neuromuscular activation pattern and the related kinematics. Measurement results should thus be used accordingly.

Keywords: *trunk flexion-extension, electromyography, kinematics, chronic back pain, age, gender*

FUNCTIONAL AND LATERAL REACH PERFORMANCE AND STANDING BALANCE DURING SENSORY CONFLICT

K. Kirilova, P. Gatev

Institute of Neurobiology, Bulgarian Academy of Sciences, Sofia, Bulgaria
Email: kat_kirilova@abv.bg

Introduction
Sensory information from different modalities should be adequately integrated for optimal standing balance. Otherwise a sensory conflict occurs which interferes with stance. Data on balance during a dynamic task in case of sensory conflict are scarce. Functional reach (FR) [1, 2] is proven to be a reliable method for falls risk assessment among elderly people. However, its modification – lateral reach (LR) [3] is less studied. Therefore we chose FR and LR as dynamic tasks to explore the influence of sensory conflict on standing balance.

Methods
Fifteen healthy right-handed volunteers (aged 28.47 ± 3.94 years, six females) performed FR and LR in four sensory conditions: eyes-open (EO), eyes-closed (EC – absence of visual information), head-extended with eyes open or closed (HE-EO or HE-EC). The last two series add conflict of vestibular origin. Subjects were instructed to reach forward, left and right as far as they could without knee flexion or foot lifting. After holding in the farthest position for 3 seconds, an instruction for going back was given. Reach was measured in mm with a ruler fixed on a wall, the third metacarpal bone was used as a marker. Center-of-pressure (COP) sway was recorded by a pedobarographic platform Tekscan. Each recording lasted 30 s. The evaluated measures were: maximal reach, COP sway path, medio-lateral (M-L) for FR and anterior-posterior (A-P) COP sway for LR. They were further evaluated for FR by two-way ANOVA with factors: vision and head position. Statistical evaluation of the measures for LR was done by three-way ANOVA with reach direction as a third factor.

Results
During sensory conflict FR significantly shortened, especially in the case where visual and vestibular modalities were affected (HE-EC). In the FR series head extension significantly increased COP sway path but only when visual information was absent. Both COP sway path and M-L sway increased during absence of vision, no matter what the head position was. In the LR series three-way ANOVA revealed statistical significance for factors vision and head position but not for reach direction for all measures. Left and right reach significantly shortened during sensory conflict, while COP sway path and A-P sway increased. This again was most expressed when both modalities were affected. For the three tests (FR and reach to the right or left) the time spent for reach completion was about 10 s, which consists 1/3 of the recording. A tendency of overshoot when going to initial position after task completion was found for all three tests. The error was significant (verified by t-test against zero).

Conclusions
The results of our study suggest that dynamic balance and task performance are vision- and vestibular-dependent and they deteriorate in the presence of sensory conflict affecting these modalities. Both functional and lateral reach test in the sensory conflict context can serve as their sensibilized variants for early risk of fall detection and prevention.

Keywords: *dynamic balance, center of pressure, posture and movement, sensory integration*

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POSTURAL REACTIONS IN PARKINSON´S DISEASE PATIENTS WITH AND WITHOUT FREEZING OF GAIT

[1,2]**Z. Košutzká**, [3]O. Pelykh, [1,4]G. Brecl-Jakob, [2,5]P. Valkovič, [1]K. Bötzel

[1]*Department of Neurology, Ludwig-Maximilian University, Munich, Germany*
[2]*2nd Department of Neurology, School of Medicine, Comenius University, Bratislava, Slovakia*
[3]*Department of Orthopaedic Surgery, Physical Medicine and Rehabilitation, Ludwig-Maximilian University, Munich, Germany*
[4]*Department of Neurology, University Medical Centre Ljubljana, Ljubljana, Slovenia*
[5]*Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia*
Email: zuzanakosutzka@gmail.com

Introduction
In advanced Parkinson's disease, patients experience postural instability including episodes of freezing of gait (FOG) and subsequent falls. Whereas bradykinesia, rigidity and tremor respond well to dopaminergic treatment, the management of FOG is more complicated and its nature is far from understood. In this study we aim to study pathophysiology of two specific features of the postural reactions uniquely in patients with and without FOG: 1. self-initiated anticipatory postural adjustments (APA's) - the preparatory phase before a step which consists of a sequence of small leg movements which shift the body weight to the stance foot to allow for the swing foot to be lifted to take a step; 2. reactive postural reflexes examined with pull test (rapid shoulder pull backwards).

Methods
We recruited 33 mild to moderate Parkinsonian patients who were dichotomised into two groups - "non-freezers" (n=19, mean age 68.2, SD 8.5) and "freezers" (n=14, mean age 72.6, SD 3.3). Presence of FOG was evaluated with item 3 from Freezing of Gait Questionnaire. All patients were "OFF-freezers". 24 healthy controls (mean age 67.4, SD 6.2) also participated on the study. All patients were examined in the best "ON" state to minimise involuntary movements. APA's were measured on the force distribution measurement system FDM-T (Zebris medical GmbH, Germany) at a sampling frequency of 100 Hz. Participants were asked to silently count to three before taking a step. Firstly, they were instructed to take a forward step five times starting with right foot and five times with the left one. Secondly, they were asked to take five times two steps starting with right foot and analogically with the left one. Pull test was executed as recommended in MDS-UPDRS. In total ten pull tests were recorded and these were divided with one five minute break in the middle.

Results
APA parameters: The length of the APA path in anterior-posterior direction seemed to be different in the three groups but this difference scarcely failed to reach statistical significance (f: 37, df=2, p=0.059). The length of the APA path in anterior-posterior direction was significantly correlated with the Hoehn&Yahr score (r=0.38; p=0.01) as well as with the FOG score (r=0.27; p=0.04) but not with age nor with duration of disease. Pull Test parameters: For the variable 'number of steps' there was a significant effect of 'group' (F=20, df=2, p=0.01). The latency of the first step was not different between the groups. Concerning the duration of the first step the factor 'group' was significant (F=43, df=2, p=0.001) as well as the length of the first step (F=45, df=2, p=0.001). Differences of step length between freezers and both other groups were significant, but not differences between control group and non-freezers. The velocity of the first step was significantly different for all groups (F=19, df=2, p=0.01).

Conclusions
Concerning the APA values, only the length of the COP in backward direction showed a tendency to be shorter in freezers but this was not significant (p=0.059). In the pull-test, latency of the compensatory step did not differ between the groups. Non-freezers needed more steps to stabilize, steps were lasting longer but were not shorter in comparison with the control group. Freezers needed even more steps than non-freezers, had a longer duration and shorter length of the steps with a reduced step velocity. The main result concerning the pull-test is that it is not a prolonged reaction time which inhibits efficient compensation of an equilibrium-threatening perturbation. It is rather a reduction of step length (significant only in freezers) and reduced step velocity which impairs sufficient compensation.

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AN ALGORITHM FOR THE AUTOMATIC SEGMENTATION OF SIT TO STAND AND STAND TO SIT TRANSITIONS

[1]**J. Krohova**, [2]S. Mellone, [1]M. Smondrk, [2]L. Chiari

[1]*Dept of Cybernetics and Biomedical Engineering, Technical University of Ostrava, Ostrava, Czech Republic*
[2]*Dept of Electrical, Electronic, and Information Engineering, University of Bologna, Bologna, Italy*
Email: jana.krohova@vsb.cz

Introduction

The quantification of physical capability is very important for the evaluation of the quality of life in subjects with limited mobility. Repeated sit to stand transitions are commonly used to assess functional lower limb muscle strength and may be useful in quantifying functional change of transitional movements. The main aim of this study was to develop a new method based on a single wearable inertial sensor for the automatic detection of Sit to Stand (SiSt) and Stand to Sit (StSi) sub-phases and validate the algorithm performance against well-established gold standards in movement analysis such as force plates and optical motion systems.

Methods

Twenty healthy young subjects with mean age 27.5 years participated in this study. Subjects sat on a chair with arms folded across chest, their back in an upright position and both feet in a comfortable position for raising up. The chair had no backrest and armrests. A Five Times Sit to Stand Test (5STS) was performed in three different conditions: at a self-selected "natural" speed, at a slower speed and as quickly as possible. Sub-phases of 5STS were defined as: the start of SiSt, the seat off phase, the end of SiSt, the start of StSi, the seat on phase, and the end of StSi. Movement analysis was performed by means of the optical motion system BTS SMART-D, a Bertec 4060-08 force platform (FP) and an inertial measurement unit, which was attached on a planar rigid cluster of markers and placed over the fifth lumbar vertebra (L5), chosen for its position close to the centre of body mass. Sensor data were sampled at 100 Hz and filtered at 2.5 Hz. Phase separation and timing of the SiSt and StSi were performed mostly using gyroscopic data and Euler Angles. In order to investigate the agreement between the proposed algorithm and the gold standard we calculated the Bland and Altman Upper and Lower Limits of Agreement (ULoA and LLoA) and the intra-class correlation coefficient ICC(1,1). There is evidence that the height of the participants can be one possible factor contributing to the difference between the seat-on time estimated with the wearable sensor and the motion analysis system. Correlation analysis was performed in order to verify this hypothesis.

Results

ICC values were always excellent, but results were sensitive to the speed of execution. At higher speed ICC were usually better than at self-selected speed and lowest agreement was obtained at slow speed. Highest values were observed for the whole duration of the test, ranging from 0.999 to 1 and smaller but still very high values were observed for the SiSt phase with ICC values ranging from 0.964 to 0.989; StSi duration showed ICC values ranging from 0.984 to 0.991. LLoA values for the total duration of the 5STS test ranged from -0.231 to -0.126 and ULoA values ranged from 0.115 to 0.192. LLoA values for the duration of the SiSt transition ranged from -0.115 to -0.071 and ULoA values ranged from 0.079 to 0.169. LLoA values for the duration of the StSi transition ranged from -0.161 to -0.084 and ULoA values ranged from 0.073 to 0.111. Results of the correlation analysis showed that there is a significant positive correlation between height of the subject and the absolute difference between estimated seat-on times for each speed.

Conclusions

The proposed algorithm demonstrated an excellent agreement with the gold standard used in movement analysis for detecting all the different sub-phases in a 5STS test. The algorithm performed better than the automatic algorithm proposed by Zijlstra et al. [1]. The presented algorithm should be further adjusted and validated on pathological subjects such as frail elderly, Parkinsonian patients, and stroke patients.

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HIP AND PELVIS STABILITY IN PATIENTS UNDERGOING TOTAL HIP ARTHROPLASTY

[1,2]**E. Kubonova**, [1]Z. Svoboda, [1]M. Janura, [3]J. Gallo, [1]Z. Novakova

[1]Faculty of Physical Culture, Palacky University, Olomouc, Czech Republic
[2]Faculty of Medicine, University of Ostrava, Ostrava, Czech Republic
[3]Department of Orthopaedic Surgery, University Hospital, Olomouc, Czech Republic
Email: kubonka@gmail.com

Introduction

Hip joint stability after total hip arthroplasty (THA) is one of the most significant factor, which is in the interest not only of surgeons as an indicator of the surgery success, but also of patients. Functional stability (variability) ensuring, especially of the hip joint, is a dominant function for economic performance of common daily activities, not only in these patients [1, 2]. However, according Hamill et al. [3] variability of the hip would consider as coordinative, which furthermore defines mutual relationship between the movement of the segments or joints. He also highlights a significant relationship of structure and function of the entire movement. In clinical practice we were interested whether we could consider a variability of the hip joint and pelvis movement, between operated and non-operated lower limb (before and after surgery), as an indicator of stability.

Methods

An experimental group consisted of 7 patients (3 women and 4 men) after total hip unilateral arthroplasty (average age 58.9±11.6 years, height 173.2±9.7 cm, weight 84.6±13.5 kg, time after surgery 8.6±5.8 months). For obtaining hip joint and pelvis kinematic parameters during gait the optoelectronic system Vicon MX (Vicon Motion Systems, OxfordMetricsGroup, London, Great Britain) was used. Five gait trials (before and after surgery) were assessed for each subject. Statistical analysis was performed using STATISTICA 12.0 (StatSoft, Inc., Tulsa, OK, USA). Comparison of mean values of the variation coefficient on operated and non-operated limbs was performed by effect size (Cohen's d). The values between 0.5 and 0.8 were considered as moderate effect and values higher than 0.8 as large effect.

Results

Bigger variability in range of motion (ROM) during gait (moderate effect) was found in hip joint in each of anatomical plane for non-operated limb (before the surgery). For pelvis movement we found also a bigger variability of ROM (large effect) in frontal plane for non-operated limb. After the surgery the values of variability of ROM for operated limb were significantly increased against ROM before the surgery, especially in transversal and frontal plane (large effect) for both the hip and pelvis.

Conclusions

Bigger hip and pelvis variability of ROM of non-operated lower limb before the surgery suggests for larger coordinative variability and therefore more physiological. After the surgery increasing variability of ROM (hip and pelvis) for operated limb can similarly point out to increased coordinative variability [3]. This could be one way of assessing joint movement, not only after THA.

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POSTURAL REACTIONS TO VISUAL SCENE MOVEMENTS IN ELDERLY PATIENTS WITH INSTABILITY AND DEMENTIA

[1,2]**M. Kucharik**, [2,3]M. Saling, [4]J. Pucik J, [4]T. Lukac

[1]National Institute of Cardiovascular Diseases, Bratislava, Slovakia
[2]Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia
[3]2nd Department of Neurology, Faculty of Medicine, Comenius University and University Hospital, Bratislava, Slovakia
[4]Institute of Electronics and Photonics, Slovak University of Technology, Bratislava, Slovakia
Email: neuro.kucharik@gmail.com

Introduction

Dysequilibrium of upright posture is very common in senior patients, even more frequent in patients with cognitive impairment [1, 2]. The instability of stance may often results in falls and serious injuries. The purpose of present experiment was to investigate whether and how the visual scene movements affect undisturbed upright stance control in healthy elderly and demented patients with instability. Visual scene movements induce visual illusion of movement and subjects have to correctly evaluate the contents of visual information [3]. We supposed that demented elderly patients have decreased adaptability to illusion movements.

Methods

Nine healthy elderly (3F, mean age 69.3±3.8 yrs) and twelve patients (6F, mean age 70.6±10.2 yrs) with different types of dementia took part in experiments. Centre of pressure (CoP) displacements were recorded using force platform. Participants stood quietly on the platform at a distance of 50 cm from the wide-screen visual scene display. The quite stance (50 seconds) was perturbed by constant linear or rotational visual scene motion (20 sec).

Results

Constant visual scene motion induced so called ON effect - forward body leaning. The opposite OFF effect was observed at the stop of visual scene motion. Rotational visual scene induced similar but less pronounced ON and OFF effect in medio-lateral direction. The maximal CoP displacement in anterio-posterior and medio-lateral direction was computed. The visual scene motion induced significantly larger CoP displacements and significantly larger velocity index of body sway in demented patients when compared to healthy elderly. Also, the postural responses to visual scene perturbation were less variable in patients with dementia than in control group.

Conclusions

Our findings suggest that elderly patients with dementia show increased sensitivity to visual scene perturbation. They need larger effort to stabilize posture then control group and they are more sensitive to visual input, i.e. visual illusion. It seems that the processes of re-weighting sensory inputs in patients with dementia are altered. Therefore visual influence may disturb upright stance in varying environment.

Keywords: *posture control, visual perturbation, dementia, posture instability*

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What does spinning tell us about shaking?

[1]**M. Lakie**, [2]C. Vernooij, [3]C. Osler, [4]A. Stevenson, [5,6]J. Scott, [1]R. Reynolds

[1]*University of Birmingham, UK*
[2]*Aix-Marseille Université, Marseille, France*
[3]*University of Derby, UK*
[4]*King's College London, UK/ QinetiQ, UK*
[5]*Wyle GmbH, Köln, Germany*
[6]*European Space Agency, Köln, Germany*
Email: m.d.lakie@bham.ac.uk

Introduction
The peak frequency of human postural tremor has been claimed to be a reflection of a central oscillator [1] and it has been suggested that such an oscillator plays a fundamental role in the control of movement [2].

Methods
We have challenged this theory by spinning experienced male subjects (n=7, mean age 35±5 yrs) in a human centrifuge at up to 3.0 g and recording their postural hand tremor while they maintain their hand in a horizontal position. In a follow-up experiment, the same subjects had their hands loaded with masses which matched the force demanded in the centrifuge and therefore required identical muscular effort.

Results
We found that tremor peak frequency increased in proportion to the increased gravitational field and therefore in proportion to the muscular effort demanded of the subjects (Fig. 1). In the case of increased mass, the effect on tremor frequency was completely different - it decreased with imposed load. This decrease in frequency has been previously observed and is predictable because added mass increases inertia which decreases resonant frequency [3].

Conclusions
There seem to be only two possible explanations for the increased tremor frequency that we observed in the centrifuge. One is a central oscillator which is uniquely responsive to gravitational field. Such an entity has never been previously suggested or observed. The second explanation, which we regard as much more likely, involves resonance. The increased muscular effort in the centrifuge will produce an increase in limb stiffness. Increased stiffness predictably raises the frequency of resonance just as increased inertia decreases it. The implication is that tremor peak frequency is almost entirely an index of peripheral resonant properties so it cannot provide a window into central mechanisms [4]. Interestingly, our experiments lead to some potentially testable predictions for tremor frequency in non-terrestrial environments.

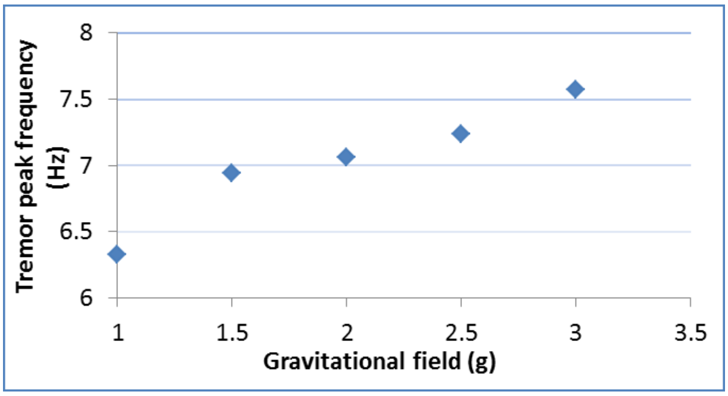

Figure 1 Variation in peak tremor frequency with altered g.

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FROZEN STIFF: CAN COOLING OF THE LOWER LIMB PROVIDE US WITH FURTHER INSIGHT INTO ANKLE STIFFNESS AND QUIET STANDING IN MAN?

A. Liedtke, R.F. Reynolds

University of Birmingham, Birmingham, UK
Email: a.liedtke@bham.ac.uk

Introduction

Balanced standing in man has long been described as an inverted pendulum with a dampened spring mass system at the ankle joint. A combination of passive intrinsic lower limb muscle stiffness and the ballistic like pattern of muscle activation produces adequate levels of torque about the ankle to allow for this to occur. Cooling has shown to cause significant increases in gastrocnemius muscle stiffness [1] and complex thixotropic properties have been shown to be attributable to this increase [2]. Effects of cooling on EMG have shown larger overall increases [3] as well as a decrease in muscle spindle activity due to an overall reduction in conduction velocity [4]. We are therefore interested how this relates to the control of quiet standing. Given that the Achilles tendon is by far the weakest link during quiet stance we anticipate that, although cooling may stiffen the muscle itself, this will not affect overall ankle stiffness. We do however anticipate a reduction in muscle length changes as a result of an overall stiffer muscle.

Methods

Data was collected from six adult subjects (30±2.8 yrs) before and after cooling. We measured ankle stiffness, using a custom made previously validated apparatus [5], as well as ultrasonically derived fibre length changes as a result of a 3° sinusoidal stretch. EMG of the medial gastrocnemius muscle was recorded throughout. Cooling of the lower limb was achieved through submersion in a 10±2° water bath for a duration of 30 minutes. Data was collected at ankle torques nearing 0 Nm (passive) as well as torques equivalent to normal standing for each particular individual (active).

Results

Significant differences were observed in relative ankle stiffness when comparing passive to active data as well as across the different perturbation magnitudes used for determining stiffness (linear mixed effects model - LME, $p<0.05$, n=6). No significant differences were observed for neither passive nor active data at all magnitudes due to cooling. Relative muscle length changes showed no significant differences due to cooling (Fig. 1). Significant differences again were seen as a result of whether the testing condition was passive or active (LME, $p<0.05$, n=6).

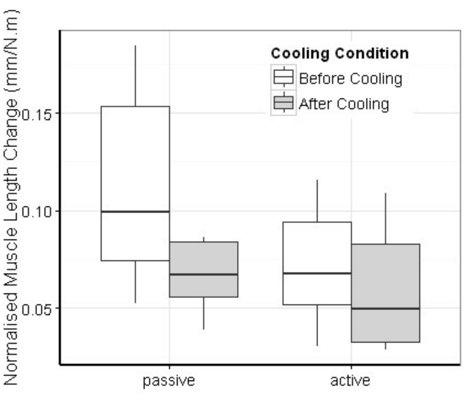

Figure 1 Boxplot showing normalised relative muscle length changes for both active and passive conditions pre and post cooling.

Conclusions

As predicted no significant differences were observed as a result of cooling on overall ankle stiffness. Differences observed across data being collected in a passive or active setting were expected due to the nature of how ankle stiffness is directly correlated to the torque produced at the ankle. Although we expected to see a significant reduction in muscle length changes, due to inter subject variation there was no significance, a trend toward this was still observed particularly when changes were normalised against baseline torque. Interestingly though, particularly for the passive data, inter subject variation markedly reduced as a result of cooling. This could potentially be due to the thixotropic effects of the muscle.

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USE OF A NOVEL DYNAMIC BALANCE MEASUREMENT SYSTEM TO EXAMINE BALANCE CONTROL IN AGING

V. Linnamo, J.M. Piirainen, T. Heikkinen, N. Sippola, N.J. Cronin, J. Avela

Department of Biology of Physical Activity, University of Jyväskylä, Finland
Email: vesa.linnamo@jyu.fi

Introduction

Balance control is associated with several human functions. Maintenance of posture requires sensory information, selection of a response and activation of the appropriate muscles to overcome balance disturbances. Although balance is typically measured using static balance tests it is possible that static balance tests may not reveal balance disorders or age-related differences as clearly as dynamic balance measurements. Therefore our aim was to develop a dynamic balance measurement system to examine if a sudden balance perturbation would differentiate the responses between young and elderly subjects better than static balance test. In addition, several neuromuscular responses were measured.

Methods

Young (N=10, 20-32 years) and Elderly (N=20, 60-72 years) male subjects took part in several balance measurements before and after a 12-week explosive strength training program. The first prototype using vertical perturbation included the frame of the system, pneumatic and control parts and a safety frame [1, 2]. Cylinders (Pimatic, P2520-40/16-125, Polarteknik PMC Oy Ab; Vantaa, Finland) were placed in each corner, one centimetre inside each edge. The cylinder displacement was 125 mm giving the plate a 12 degree dropping capacity in maximal drops. A commercial force plate (BT4 balance platform, HurLabs Oy, Tampere, Finland) was used for balance measurements. Left-right (x) and backward-forward (y) directions were used to indicate medio-lateral and antero-posterior balance displacement, respectively. Maximal swaying distance in medio-lateral (x) and anterior-posterior (y) stabilograms were analysed during a 1 second period after the disturbance with the platform remaining in the tilted position. The same force plate was used also for the second prototype using horizontal perturbation [3]. Two electromechanical cylinders (EMC, Bosch Rexroth, Germany) produced movement of the frames with a maximal amplitude of 300 mm, and maximal velocity of 70 cm/s. Balance was measured in two different conditions (Slow: max acceleration 0.3 m/s2, max velocity 15 cm/s, displacement 7.5 cm; Fast: max acceleration 4.0 m/s2, max velocity 25 cm/s, displacement 12.5 cm). COP displacement was analysed from each direction and speed. Peak displacement and time to peak displacement were analysed.

Results

Elderly individuals showed weaker balance control in the anterior-posterior direction during vertical perturbations but not in static conditions. In addition, during horizontal perturbations, the elderly showed weaker balance control than their younger counterparts during anterior perturbations. Good dynamic balance control was associated with the capability to produce force rapidly. Moreover, it was shown that with explosive strength training it was possible to improve dynamic balance control considerably.

Conclusions

It can be recommended that balance control should be measured in dynamic conditions using horizontal perturbations, which may have more functional relevance than static conditions. Explosive strength training is suggested to be beneficial for improving balance control in elderly subjects. The measurement system could also be used in athletic testing.

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OCULUS RIFT - AN ALTERNATIVE OF PROJECTION SCREEN FOR VISUAL STIMULATION

[1]**T. Lukac**, [2,3]M. Saling, [1]J. Pucik, [2,3]M. Kucharik, [1]O. Ondracek

[1]*Slovak University of Technology in Bratislava, Bratislava, Slovakia*
[2]*University Hospital Bratislava, Bratislava, Slovakia*
[3]*Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia*
Email: lukactv@gmail.com

Introduction

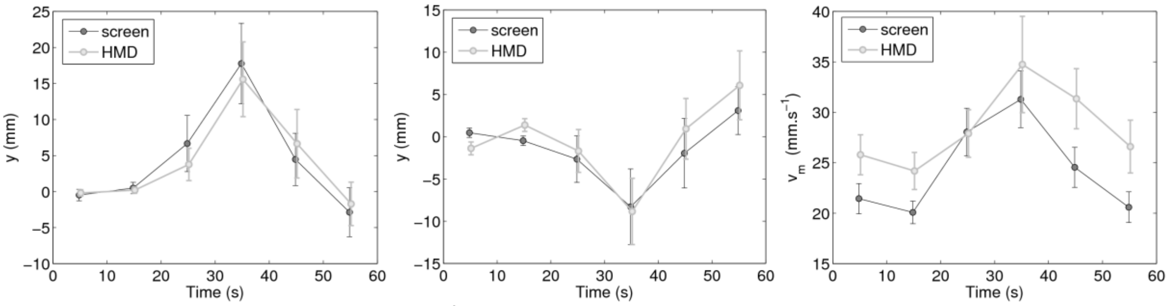
Research of vision role in postural control has a long history. The technology used to deliver visual stimuli differs in their portability and cost. In clinical settings, single rear projection screen and head mounted display (HMD) are most suitable solutions. Recently, gaming industry released lightweight, cost effective, wide field of view headset Oculus Rift. The prototype of this HMD equipped by head tilt sensor seems to be promising in biomechanical [1] and postural [2] assessments. In this work, we test equivalence of the rear projection screen system and the Oculus Rift as sources of visual perturbation for postural control research.

Methods

Participants (*n*=10, age 20-43) were presented with transient dynamic visual stimuli designed as moving camera view inside toroidal tunnel, textured with chessboard. Participants (1) stood 50 cm behind the rear projection screen and next (2) set HMD with software adjusted interocular distance. Image in HMD was predistorted to compensate for optic distortion and adjusted such that retinal optic flow is equivalent in both situations. The force plate recorded postural responses. Single measurement takes 60 s, divided equally to 20 s prestimulus, stimuls and poststimulus periods. Measurement repeated 3 times, for each technology and movement direction (forward, backward). Responses are quantified in terms of posturographic parameters – mean COP deflection and mean COP velocity in 10 s epochs, averaged over repeated measurements.

Results

Both technologies induced postural tilt in direction of visual stimuli (Fig. 1a, 1b) and instability manifested as rise in mean velocity (Fig. 1c). Amplitude deflections do not differ significantly. Mean velocity is higher in HMD measurement, velocity rise is statistically significant in epochs before and after stimulus.



(a) (b) (c)

Figure 1 Postural responses to transient visual stimuli delivered by different technologies. Stimulus is applied between 20-40 s, response evaluated on 10 s segments: (a), (b) antero-posterior sway for (a) forward and (b) backward moving stimuli; (c) mean velocity (backward scene). Error bars indicate standard error.

Conclusions

Oculus Rift HMD is an attractive alternative to conventionally used system based on projector and screen. In our experiment, perceived image in HMD stimulation is head referenced rather than laboratory referenced in screen projection case. This difference explains increase in mean velocity. Advantage of the used emerging technology is its portability, reduced cost and potential use of the head tilt sensor.

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PERCEPTION OF HEAD MOTION DURING LOCOMOTION

S.W. Mackenzie, R.F. Reynolds

School of Sport, Exercise & Rehabilitation Sciences, University of Birmingham, Birmingham, UK
Email: sxm112@bham.ac.uk

Introduction

The vestibular system, located in the non-auditory part of the inner ear, is often referred to as the 'Balance Organ' and is used for balance, orientation, reflex eye movements and perception of self motion. Here we are interested in perception of self motion during locomotion. Humans are able to distinguish between sensations that result from changes in our environment (exafference) and those that result from our own actions (reafference). Expected sensory results of motor command information is subtracted from the sensory signals to eliminate reafferent sensory information [1]. This process is the reason you can't tickle yourself [2]. Research investigating the suppression of vestibular reafference clearly shows that suppression does occur [3,4] with reports of attenuation of 70% in a population of vestibular neurons during passive motion. Whether these neurophysiological findings translate to altered perception has yet to be investigated. In this study we determine whether perception of head motion is suppressed during locomotion.

Methods

We tested sensory perception of head motion during locomotion in nine participants (6 male) aged 21-40 (mean ± SD: 26.5 ± 5.6), who were healthy with no known neurological or vestibular disorders. Participants wore a head unit attached to a linear actuator located on a backpack. In the passive state, this actuator could be used purely as a motion sensor, to measure head pitch. In the active state, it could be used to physically move the head in pitch. Participants walked at three speeds (1.0, 1.2 and 1.4 m/s) on a treadmill, eyes closed, for 90 s. After the active walking phase, they stood still, and the linear actuator replayed the exact recording of the head motion experienced during the previous walking trial. As the motor moved the participants head, they were instructed to manipulate the magnitude of the motion, via a hand-held dial, so that they perceived the same head motion as experienced during the active walking phase.

Results

Perceived magnitude of head pitch motion was ~80% less than actually experienced during walking ($t(2)=135.3$, $p<0.001$) (Fig. 1). This was seen across all speeds. This effect was also confirmed by motion capture markers, in addition to the linear actuator sensor.

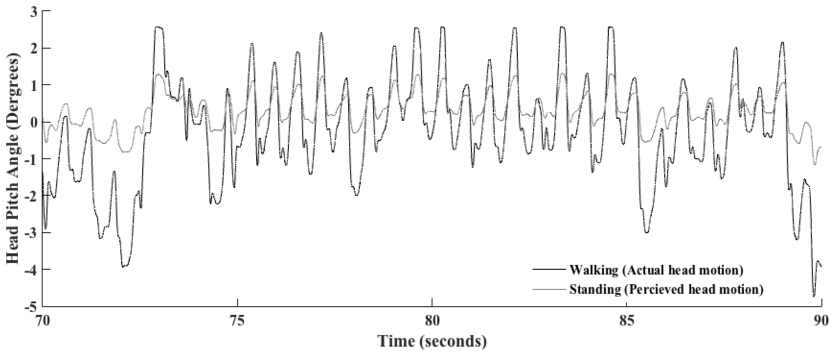

Figure 1 Single trial representation of head motion during locomotion and perceived head motion. Walking speed of 1.0 m/s is presented. Solid black lines represent actual head motion during locomotion while solid grey lines represent perceived head motion.

Conclusions

Young healthy individuals perceived head motion to be far less than the actual motion occurring. We attribute this to a suppression of reafferent sensory feedback during locomotion. This could occur via a prediction of sensory feedback based upon motor output. Such suppression may increase vestibular sensitivity to unexpected external perturbations, which may be important in preventing falls.

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Postural stability of elite womens football players

T. Malý, F. Zahálka, L. Malá, E. Vaidová, T. Gryc, P. Hráský

Charles University, Faculty of Physical Education and Sports, Prague, Czech Republic
Email: maly@ftvs.cuni.cz

Introduction

The aim of this study was to compare the postural stability focused on one leg standing mainly with the symmetry distribution of muscular mass of lower extremities through selected parameters of body composition. During the football match both lower limbs are loaded asymmetrically and it can have morphological effect of muscle hypertrophy [1]. Postural stability is in close relationship with balance capabilities which could on one side increase movement and sporting performance, and on other side could decrease injury risk [2].

Methods

The participants of this study were twenty female football players of Czech national team (n = 20, age 23.3 ± 4.3 years; body height 167.2 ± 6.4 cm; body mass 60.9 ± 5.3 kg). Postural stability was measured by pressure plate FootScan (RScan, Belgium) and test on one lower extremity only (Flamingo test) with length 60 sec. The main evaluation parameter for postural stability was movement of Centre of Pressure, resp. Centre of Forces during the standing by help of parameter Total Traveled Way (TTW). Segmental fluid distributions of lower extremities (liters) were measured by multifrequent bioimpedancy analyzer InBody 3.0.

Results

Difference during comparison of means stability in test called Flamingo – right lower extremities (889.0 ± 463 mm) and left extremities (831.9 ± 328 mm) wasn't significant ($p>0.05$) and it was according to our expectance. When we evaluated the Total Traveled Way of Center of Pressure (COP) during selected test of postural stability, the mean value of difference between lower extremities was 23.38 ± 31.52 %. Analysis of correlation between morphological dysbalances and differences in stability didn't demonstrate significant correlation ($r=0.01$; $p>0.05$). Conversely, the relation appears to be orthogonal. Mean value of fluid distribution in the right, resp. left lower extremities was 5.98 ± 0.61 l, resp. 6.03 ± 0.62 l ($p<0.01$) and this difference was significant. Asymmetric fluid distribution between the right, resp. left lower extremities was measured in four players (20 %).

Conclusions

Selected and monitored group was homogenous from point of view postural stability and morphological selected parameters. There were no significant correlations between postural stability parameters and fluid distribution of lower extremities. One of the reasons could be lower number of participants and next research is focused to increase number of women football players from elite and top elite group of players.

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PROPRIOCEPTIVE DOWN-WEIGHTING IN TOXIC NEUROPATHY (CIPN) AND EFFECTS OF BALANCE TRAINING

[1]**C. Maurer**, [2]S. Kneis, [2]A. Wehrle

[1]*Neurology, University Freiburg, Germany*
[2]*Sports Science, University Freiburg, Germany*
Email: christoph.maurer@uniklinik-freiburg.de

Introduction
It is well known that neuropathy is associated with postural instability. Symptoms include increased sway amplitudes, velocities, a shift of postural strategy from ankle to hip, and the use of vestibular instead of somatosensory cues. However, there are only few studies that systematically evaluate the role of sensory, motor, and central adaptation mechanisms for the abnormal postural control in neuropathy. Using a model-based approach, we aimed to identify and quantify these basic postural mechanisms. Moreover, we were interested in evaluating the benefit of balance training and its influence on the basic postural mechanisms mentioned above.

Methods
We analyzed postural control in eight patients, median age 63,5 years (42-68; male:female = 6:2), who were homogenously suffering from toxic, chemotherapy-induced peripheral neuropathy (CIPN), before and after one-on-one training sessions twice per week over 12 weeks. The findings were compared to data from 15 matched healthy subjects. Postural control was characterized by spontaneous sway measures and measures of perturbed stance. Perturbations were induced by pseudorandom tilts of the body support surface in the sagittal plane.

Results
We found that spontaneous sway amplitude and velocity were significantly larger in CIPN patients compared to healthy subjects. Gain profiles as a function of external stimulus frequencies, amplitudes, and visual conditions were significantly different in CIPN patients compared to healthy subjects. Based on simple feedback model simulations, we found that healthy subjects and CIPN patients primarily differ in the use of proprioceptive cues. From a clinical perspective, this was not too surprising since proprioception carries the main deficit in neuropathy. Balance training ameliorated balance skills in CIPN patients on a clinical basis. Interestingly, training precisely modified the major postural abnormality in CIPN patients, i.e. it significantly up-weights proprioception. This seems to be a paradoxical strategy to help patients suffering from a proprioceptive deficit. We argue that CIPN patients' proprioceptive down-weighting before training does not purely represent their deficit, but rather indicates an excessive compensation mechanism, as they primarily rely on space cues.

Conclusions
We propose that the high efficacy of training is mainly based on the correction of this excessive compensation. As a positive side effect of the sensory reweighting after training, vestibular cues were down-weighted, thus leading to reduced vestibular noise and consequently to normalized sway amplitudes and a higher postural stability after intervention.

A PROTOCOL TO ASSESS LOCOMOTOR PLASTICITY AND DYNAMIC GAIT STABILITY USING THE COMPUTER ASSISTED REHABILITATION ENVIRONMENT

[1,2]**C. McCrum**, [1]P. Willems, [2]K. Karamanidis, [1,3]H. Kingma, [2]W. Zijlstra, [1]K. Meijer

[1]Maastricht University Medical Centre+, Maastricht, The Netherlands
[2]German Sport University Cologne, Cologne, Germany
[3]Tomsk State University, Tomsk, Russia
Email: chris.mccrum@maastrichtuniversity.nl

Introduction

Assessing gait stability is important in persons at an increased falls risk. We aimed to develop a protocol to assess dynamic gait stability and adaptation, including inter-limb transfer, using gait perturbations.

Methods

The protocol uses the dual-belt treadmill Computer Assisted Rehabilitation Environment (CAREN; Motek Medical, Amsterdam). The perturbation is a 3 m/s^2 acceleration of one belt from walking speed to a peak speed (walking speed + chosen perturbation intensity [out of 10] x 0.2), starting at midstance of the prior step, causing a posterior acceleration of the stance limb for the entire stance phase. The protocol includes five minutes of non-perturbed walking followed by 10 perturbations over 10 minutes, separated by non-perturbed walking (30 to 90 s; randomised to reduce predictability). The right belt is accelerated first, followed by eight left belt accelerations, and ending with a right belt acceleration. To assess gait stability, five markers (C7, left and right trochanter and hallux) are tracked via motion capture (Vicon Nexus). The margin of stability (MoS) is calculated at touchdown in the anteroposterior direction [1] with a reduced kinematic model [2] in real time by the CAREN D-Flow software. Gait events are detected using the hallux markers [3]. We piloted the protocol with a healthy male (age 24) with a speed of 1.4 m/s and a change in belt speed of 1.4 m/s to 2.6 m/s.

Results

MoS after the 9th perturbation showed adaptations, being higher at 9post2L than at 2post2L, with more consistent later steps. Inter-limb transfer from perturbations 1 to 2 were found. Unexpectedly, 10post2R was less stable than 1post2R. Further results under different conditions will be presented at the symposium.

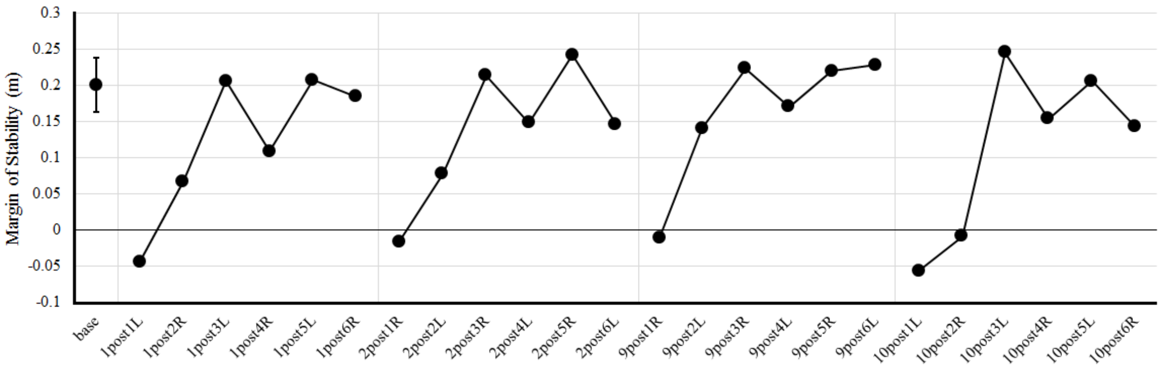

Figure 1 The MoS at touchdown during non-perturbed walking (base: mean±SD of 12 steps) and the first six steps following the 1st, 2nd, 9th and 10th perturbations to the right, left, left and right legs, respectively.

Conclusions

This locomotor plasticity assessment protocol can assess a multitude of locomotor characteristics in a short space of time using the CAREN and could benefit both clinicians and researchers working with groups at an increased falls risk such as elderly or individuals with stroke or balance disorders.

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SENSORY CONTRIBUTIONS TO STANDING BALANCE IN UNILATERAL VESTIBULOPATHY

[1,2]**C. McCrum**, [3]K. Eysel-Gosepath, [2]G. Epro, [2]G.P. Brüggemann, [2]K. Karamanidis

[1]*Maastricht University Medical Centre+, Maastricht, The Netherlands*
[2]*German Sport University Cologne, Cologne, Germany*
[3]*Heinrich Heine University of Düsseldorf, Düsseldorf, Germany*
Email: chris.mccrum@maastrichtuniversity.nl

Introduction

Preserving upright stance requires complex central integration of vestibular, visual, proprioception and neuromuscular systems in order to keep the centre of mass within the limits of the base of support. Patients with unilateral peripheral vestibular disorder (UPVD) have diminished postural stability [1] and therefore the aim of this study was to examine and compare the contribution of multiple sensory systems to static postural control in UPVD patients and healthy subjects during upright standing. We hypothesised that disturbance of visual and proprioceptive systems will augment the postural sway in patients with UPVD more than in healthy subjects.

Methods

Seventeen middle-aged adults with UPVD and 17 age-, sex-, height- and body weight-matched healthy control subjects participated in this study. Centre of pressure (COP) trajectories under the feet were assessed using a custom made force plate during six different postural tasks. Forwards and backwards leaning was conducted in order to determine the individual limits of stability of the subjects. Following the leaning tasks, upright quiet standing with and without Achilles tendon vibration, each with eyes open and eyes closed, was assessed. All tasks were repeated three times, with the trials with the most posterior or anterior COP position for the leaning task being used in the analysis, and with the mean values of the upright standing tasks being used for further analysis. Postural standing stability was evaluated over 30 seconds by means of the following parameters: the total excursion distance of the COP (COP_{Path}) and the distances between the most anterior and posterior points of the COP_{Path} and the anterior and posterior anatomical boundaries of the base of support (COP_{Amin} and COP_{Pmin}). In addition, the corrected COP_{Amin} and COP_{Pmin} was assessed by taking the corrected base of support boundaries into account using the anterior and posterior COP data from the leaning tasks. A two-way repeated measures ANOVA, with subject group and task condition as factors, was used to identify potential differences in the analysed parameters.

Results

UPVD patients showed a tendency for smaller limits of stability during the leaning tasks in both directions. Significant subject group and task condition effects were found ($P<0.05$) for COP_{Path} (i.e. higher values for patients compared to controls) with no subject group x task condition interaction. UPVD patients showed significantly ($P<0.05$) lower COP_{Pmin} values compared to the control group for all conditions. These differences were more pronounced when the corrected COP_{Pmin} was considered. Contrary to the posterior direction, there were no significant effects for the COP_{Amin} or the corrected COP_{Amin}. Disturbance of the visual system alone lead to a distinct postural backward sway in both subject groups which became significantly more pronounced in combination with Achilles tendon vibration.

Conclusions

It appears that during quiet standing, disturbance of the visual and proprioceptive systems represents a method to analyse sensory contributions to postural control. UPVD patients show particularly marked decreases in postural stability with visual and proprioceptive sensory disturbance. Additionally, the individual limits of stability should be considered in future research when conducting posturographic measurements in vestibulopathy patients, as these differences to healthy subjects may lead to erroneous comparisons.

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Dry immersion as a therapeutic intervention to improve motor and non-motor deficits in Parkinson's disease patients: a feasibility study

[1]**A. Meigal**, [2]I. Saenko, [3]L. Chernikova, [1]L. Gerasimova-Meigal, [1]N. Subbotina

[1]Institute of Advanced Biomedical Technologies of Petrozavodsk State University, Petrozavodsk, Russia
[2]State Scientific Center – Institute of Biomedical Problems (IBMP), Moscow, Russia
[3]Scientific Center of Neurology, Moscow, Russia
Email: meigal@petrsu.ru

Introduction
The "dry immersion" (DIM) technique stands for immersion without direct contact with water. DIM is used as analogue microgravity in the space-related ground-based experiments, and it is reportedly potent in decreasing muscle tone [1]. Presumably, DIM may exert therapeutic effect on motor disorders in Parkinson's disease (PD), e.g. tremor, rigidity, akinesia and postural instability. In this feasibility study we focused on the general effect of DIM on PD patients with special reference to body balance.

Methods
16 dwellers of the city of Petrozavodsk participated in this single-group, pre/post-test study on their informed consent. During DIM a subject floated in a tub (MEDSIM, IBMP, Moscow, Russia, Twater = 31°C), wrapped in a thin waterproof material. 7 patients were excluded due to unstable blood pressure (BP) during test immersion. Of the remaining 9 patients (5 M, 4 F, mean age 66.7 years), 6 had PD and 3 had vascular parkinsonism (H&Y stage 2-2.5). Course of DIM included 7 immersions (45 min, 2 times per week, head out of water), on-medication. Unified Parkinson's disease rating scale (UPDRS), frontal assessment battery (FAB), the Hamilton's depression rate scale (HDRS), autonomic nervous dysfunction questionnaire, Montreal cognitive assessment (MOCA), Spielberger's State-Trait Anxiety Inventory (STAI), mini-mental state examination (MMSE) and SF-36 were applied before the 1st, after 4th, 7th immersion, and 2 weeks (2W) and 2 months post-DIM. The body balance was evaluated by stabilometry (ST150, MERA, Moscow, Russia) with eyes open and closed (30 s each), using length (Lo, Lc, mm), velocity (Vo, Vc, mm/s) and square (So, Sc, mm2) of the center of gravity sway. Surface electromyography (sEMG) in brachial biceps muscle was recorded before/after each immersion bilaterally, at rest and at loading [2]. Heart rate variability (HRV) and BP were monitored during immersion. Statgraphics 15.0 Centurion (StatPoint Technologies, Inc., Warrenton, USA) was used for statistics.

Results
UPDRS score has decreased from 62 (46-79, 25-75%) to 51 (33-69, $p>0.05$) by the 7th immersion, and further to 48 ($p<0.05$) 2W post-DIM. The UPDRS-III has decreased from 36 (26-47) to 29 by 2W post-DIM ($p=0.063$). FAB score changed from 15.8 (14.5-17.5) to 17.3 (17-18, $p<0.05$), HDRS - from 11.5 (6-16) to 7.5 (2-9, $p<0.05$), the autonomic nervous system scale score - from 19.5 (9-34) to 13.2 (5-16, $p<0.05$) 2W post-DIM. MOCA, MMSE, SF-36 and STAI tended to improve under DIM, though insignificantly. 2 months post-DIM all studied parameters regained the pre-DIM values. The stabilometric parameters in "eyes-open" condition have insignificantly increased by 2W post-DIM: Lo - from 277 to 296 mm, Vo - from 9.3 to 9.8 mm/s, and So - from 228 to 282 mm2. Under "eyes-closed" condition Lc has changed from 598 to 543 mm, Vc from 19.9 to 17.6 mm/s, and Sc from 390 to 457 mm2. 2 months post-DIM these shifted back. Visually, sEMG amplitude and clustering has substantially decreased right after immersion.

Conclusions
Course of DIM exerted recovery effect on the autonomic, emotional, cognitive, and motor dysfunctions in PD patients which persisted for at least 2 weeks after its completion. However, a positive effect of DIM on the body balance was not that notable. We assume that decrease of muscle tone and BP induced by DIM may account for that. In further analysis, motion video capture and non-linear parameters would have been helpful assessing gait recovery and sEMG modification under DIM [2]. Also, patients at earlier stages of PD (1-1.5 H&Y) could have presented better compliance to DIM intervention.

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Postural disorders diagnostics using the method of postural somatooscillography (PSOG)

[1]**R. Melecký**, [2]E. Rašev, [3]D. Novák, [1]J. Jeřábek, [1]K. Hána, [1]J. Mužík, [1]P. Smrčka, [1]J. Kašpar

[1]Joint Department of Biomedical Engineering CTU and Charles University in Prague, Prague, Czech republic
[2]Charles University, Faculty of Physical Education and Sport, Prague, Czech republic
[3]Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Cybernetics, Prague, Czech republic
Email: roman.melecky@fbmi.cvut.cz

Introduction

The Postural Somatooscillography method (PSOG) applied for postural disorders diagnostics is being introduced. PSOG is actually posturography that generates a projection of COP (center of pressure) to a defined unstable platform, impeding the stabilization of the body in standardized test situations. PSOG consists of a Posturomed platform, an accelerometer mounted on the bottom surface of the platform, a measuring box, from which data are transferred to a computer where these data are collected. The method uses investigation techniques of „one leg standing" after a previous anticipation of transferring the center of gravity of defined anticipation after repeated provocative test "3 steps and 8 seconds single-leg stance". Character of the data acquired by the system resemble damped oscillations due to the efforts of a patient with postural disorder to maintain balance on the platform after execution of the provocative test. The aim of the method is to determine differences in the postural stabilization of motor function in healthy people and in people with postural instability using time-domain signal processing. Eight parameters describing the damped oscillations have been found in order to objectively quantify and classify the patient's ability of postural stabilization.

Methods

The classification algorithm was trained on a training group of 28 subjects (men and women) with postural disorders including postural healthy subjects, and all were measured by the system. Among the known pathology diagnoses were the following: pseudoradicular syndrome of the lumbar spine, pseudoradicular syndrome of the cervical spine, whiplash injury and instability of the knee joint and healthy individuals. All probands then completed the provocative test "3 steps - standing on one leg" on Posturomed. The testing group consisted of 24 people that were selected from postural healthy, and the group of 28 people consisted of patients with obvious clinical symptoms of postural dysfunction. The average age for both groups is very close, in the group of PD patients the average age had the value of 41.11 years while in the control group CG the average age was 40.67. The Body Mass Index for both groups is also well comparable. In the group of patients its average value is 23.39 while for the control group it is 23.04. The composition of the group of healthy subjects (CG): 5 of them were women with an average age of 38.8 years and an average BMI of 22, and 19 of them were men with an average age of 41.16 years and an average BMI of 23.32. The composition of the group of patients with postural dysfunction (PD) was following: 16 women with an average age of 41.25 and an average BMI of 22.13, and 12 men with an average age of 40.92 years and an average BMI 25.08.

Results

On the training group, which independence was proved with analysis of variance (ANOVA), seven parameters have been extracted. The implemented decision algorithm was taught on the training data set measured on the disengaged platform in a way that the class for each parameter has been recognized separately. We can classify into the following classes: 1) patient is stable, 2) patient is slightly unstable, and 3) patient is highly unstable. On the testing group it turned out that all probands in the CG group showed values of stability parameters significantly different from the values of PD patients.

Conclusions

Overall, the results of patients with clinically noticeable titubations who have postural dysfunction are well verifiable by the PSOG examination on the Posturomed platform.

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NEW DEVELOPMENTS IN CONTROLLING BALANCE OF HUMANOID ROBOTS WITH THE HUMAN-DERIVED DISTURBANCE ESTIMATION AND COMPENSATION (DEC) CONCEPT

T. Mergner, G. Hettich, V. Lippi, L. Assländer

Neurology, University Clinics, Freiburg, Germany
Email: mergner@uni-freiburg.de

Engineers are facing problems in mechanical human-robot interactions. One example is the lack of acceptance of technical assistive devices such as neuro-prostheses or exoskeletons by neurological patients on the long run. Using principles of human sensorimotor control may improve the human-robot interaction. On the other hand, neuroscientists often profit from engineering tools in their research. Neurorobotics is a combination of robotics and neuroscience. Our group is using it in posture control research, where findings from human balancing responses are transformed into models, which then are implemented into humanoid robots. Data from robot experiments, obtained in the same testbed as the human subjects, are then compared with the human data to test how well the model describes the human principles under real world conditions (including noise and inaccuracies of sensor, etc.). The model used for the control of balancing uses sensory-derived internal reconstructions of the external disturbances having impact on the body posture to compensate them through joint torques [1].

This contribution provides an overview of new developments made with the neurorobotics approach in human posture control research. Specifically, it addresses four issues:

(a) *Movement synergies emerging from DEC control*. Human sway responses in hip and ankle joints to support surface tilts were analyzed and described by a two DEC modules, which are interconnected on the sensory level [2].

(b) *Involvement of more than two degrees of freedom (DOF)*. The principles obtained in (a) lend themselves to a modular control structure. The structure can easily comprise several DOF, since the control complexity increases only linearly with the number of DOF [3].

(c) *Testing DEC model on robotic platform of other groups*. The findings of (b) were successfully tested in the control of the humanoid robot Toro from the DLR (German Aerospace Center) (see www.posturob.de).

(d) *Using our robot PostuRob II as a platform for testing concepts of other posture control researchers*. The theoretical Eigen-synergy concept of [4], where the inter-joint coordination originates in the controller, was implemented in PostuRob II [5] (see www.posturob.de).

Taken together, the re-embodiment of human posture control mechanisms in a humanoid robot provides engineers with an explicit description of human sensorimotor control and neurologists with the possibility to test their hypotheses of posture control functions and problems under real-world conditions.

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APPLYING MULTIPLE PERTURBATIONS AND SYSTEM IDENTIFICATION TECHNIQUES TO ASSESS THE UNDERLYING SYSTEMS INVOLVED IN STANDING BALANCE

[1]**J.H. Pasma**, [2]D. Engelhart, [3]C.G.M. Meskers, [4]A.B. Maier, [1,2]A.C. Schouten, [1,2]H. van der Kooij

[1]*Department of Biomechanical Engineering, Delft University of Technology, Delft, The Netherlands*
[2]*Department of Biomechanical Engineering, University of Twente, Enschede, The Netherlands*
[3]*Department of Rehabilitation Medicine, VU University Medical Center, Amsterdam, The Netherlands*
[4]*Department of Internal Medicine, Section Geriatrics and Gerontology, VU University Medical Center, Amsterdam, The Netherlands*
Email: j.h.pasma@tudelft.nl

Introduction

Standing balance is a complex mechanism in which several underlying systems, such as the nervous system, sensory systems and motor system, work together in a closed loop to keep the body in upright position. With age, diseases and medication use these underlying systems deteriorate, which could result in impaired balance and finally in falling. To improve standing balance with targeted interventions, it is necessary to know the underlying and primary cause of impaired balance, in which current clinical balance tests are lacking [1]. We investigated whether we can assess the contribution of the underlying systems involved in standing balance in one single test with the use of system identification techniques and mechanical and sensory perturbations.

Methods

Five healthy young participants (age 25.8 ± 2.8, 3 women) were instructed to maintain their balance, while the proprioceptive information, visual information and leg and trunk segment were disturbed by support surface rotations and visual scene rotations around the ankle axis, and force disturbances at hip and shoulder level, respectively. While the perturbation amplitude of the visual scene rotation and force disturbances were kept constant, the perturbation amplitude of the support surface rotation increased over trials. Using system identification techniques, the relation between the sensory perturbations and the joint torques and angles (i.e. the sensitivity functions) were estimated as a measure of the proprioceptive and visual weights. The relation between the joint angles and torques were estimated as measure of the behaviour of the neuromuscular controller describing the control of the ankle and hip joint as well as the intersegmental coupling. Each relation is described by a magnitude and phase representing the relation in terms of amplitude and time.

Results

The magnitude of the sensitivity function of the support surface rotations to the joint torques and angles decreased with increasing perturbation amplitude of the support surface rotation, while the magnitude of the sensitivity function of the visual scene rotation to the joint torques and angles increased. The neuromuscular controller remained constant by increasing the perturbation amplitude of the support surface rotation.

Conclusions

The results of this study show that by applying mechanical and sensory perturbations at the same time in one test it is possible to assess the underlying systems involved in standing balance and the flexible process of sensory reweighting using system identification techniques, which is not possible using current clinical balance tests. Therefore, system identification techniques will be an essential tool to use in clinical practice resulting in a more specific and differential diagnosis of impaired standing balance, which makes it possible to develop and implement targeted interventions to improve standing balance and finally reduce falling.

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NORMAL AND ABNORMAL REGULATION OF CORRECTIVE TORQUE REQUIRED FOR HUMAN BALANCE CONTROL

R.J. Peterka

Oregon Health & Science University, Portland, USA
Email: peterkar@ohsu.edu

Introduction

Considering that balance during stance is regulated by a closed-loop feedback control process, then application of appropriate system identification methods allows for a quantitative characterization of important mechanisms contributing to balance control [1]. These mechanisms include a sensory integration mechanism and a sensory-to-motor transformation mechanism. Previous work has shown that sensory integration can be represented as a weighted summation of orientation information from proprioceptive, visual, and vestibular systems with weights changing as a function of environmental and test conditions [2]. The sensory-to-motor transformation can be represented by a 'neural controller' that generates corrective joint torques in relation to body sway angle and angular velocity (i.e. proportional + derivative, or PD control). Identification of a feedback control system requires application of a perturbing stimulus, such as tilt or translation of the stance surface or the visual scene, or application of external forces (pushes/pulls) [1].

Methods

We have used primarily surface and visual scene tilts to evoke body sway and analysed the stimulus/response relationship by calculating frequency response functions (FRFs) that characterize the balance control system's sensitivity (gain) and timing (phase) of evoked body sway relative to the stimulus and as a function of stimulus frequency. Then parameters, representing sensory integration (sensory weights) and the PD neural controller parameters, can be estimated from optimal fits of a FRFs predicted by a feedback control model of the balance system to the experimental FRFs [2].

Results

Results from measurements of sensory weights will be shown for normal subjects and subjects with bilateral [2] and unilateral vestibular loss [3] to demonstrate abnormal sensory utilization in subjects with sensory deficits. But the focus will be on normal and abnormal function of the sensory-to-motor transformation mechanism represented by PD parameters of the neural controller. Previous results [2] demonstrated that normal subjects precisely regulate the amount of corrective torque generated per unit of body sway (termed the 'torque normalization hypothesis') even though stability of the balance control system does not require regulation as precise as that observed. Modelling results provide insight into what behavioural factors are optimized by the experimentally observed neural controller parameters [4]. Although apparently rare, we have identified some individual subjects with abnormalities in corrective torque generation. In particular, preliminary data from 3 subjects, with unresolved balance complaints following traumatic brain injury, showed that 2 of the 3 had reduced corrective torque generation in one particular test condition (eyes open stance perturbed by surface-tilt stimulation), but normal torque generation in other test conditions (eyes closed stance with surface-tilt stimulus and visual stimulus on fixed surface). These same 2 subjects also showed sensory abnormalities with increased visual sensory contributions to balance in the test condition that presented a visual stimulus during stance on fixed surface.

Conclusions

The application of closed-loop identification methods can provide insights into balance control abnormalities by assessing the function of both sensory integration and sensory-to-motor transformation mechanisms. The ability to accurately detect and quantify the abnormal components of the balance control system may motivate the use of rehabilitation strategies that specifically target the identified abnormality and may provide the ability to track the effectiveness of rehabilitation.

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Dynamic stability of the center of mass and the feet during gait: adults vs. children comparison

[1]**C. Pothrat**, [1]T. Galdi, [1,2]E. Viehweger, [1]E. Berton, [1]G. Rao

[1]*Institute of Movement Sciences, Aix Marseille Université, Marseille, France*
[2]*Pediatric Orthopedic Department, La Timone Hospital APHM, Marseille, France*
Email: claude.pothrat@univ-amu.fr

Introduction

Non-linear time series analyses have been widely used to quantify local and orbital dynamic stability during locomotor tasks [1]. While the lower limb stability has been assessed by previous studies [2], it remains unclear how the neuro-muscular system manages feet dynamic stability relatively to the Center of mass (CoM), as these segments undergo a lot of constraints during gait. The present study sought the short term and long term local dynamic stability as well as the orbital stability of the CoM and the feet during gait. The relationship between the feet and the CoM stabilities will be compared between adults and children.

Methods

Nine children (7.2 ± 1.9 years, 1.2 ± 0.2 m, 22.5 ± 8.2 kg) and 11 adults (27.0 ± 3.6 years, 1.7 ± 0.7 m, 68.1 ± 9.9 kg) performed a three minutes gait trial on a treadmill at normalized (Froude) speed. 60 strides were kept for non-linear analyses. A 3D accelerometer was placed on the sacrum to measure the accelerations of the CoM. Six retro-reflective markers were placed on the foot to calculate the intrinsic motion by calculating the helical angle between the rearfoot and the forefoot segments. Proper state spaces were constructed for each time series using the embedded delay method. Short term and long term Lyapunov exponents were calculated to quantify the local dynamic stability, and Floquet Multipliers for orbital stability. Balanced ANOVAs and Tuckey post-hoc test were used to assess statistical differences between conditions ($p<0.05$).

Results

In the long term, adults adopted a medio-lateral stabilization of the CoM during gait. Children showed an over-stabilization of the CoM in all directions (Fig. 1, top). A medio-lateral orbital stabilization was observed for both groups. Short term results showed no major difference between the three directions of CoM, neither in adults nor in children. However, the feet showed a clearly lower local dynamic stability compared to the CoM, which persisted on the long term in children but not in adults (Fig. 1, bottom). Strikingly, opposite results were obtained for the orbital stability, as the CoM revealed a lower stability compared to the feet, for both groups.

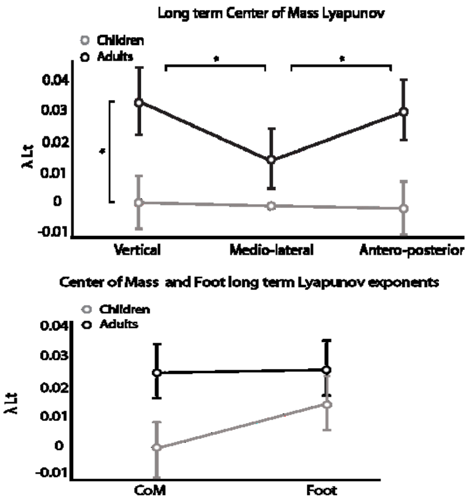

Figure 1 Long term Lyapunov exponents for the three dimensions of the CoM (top), and for the foot compared to the mean CoM acceleration (bottom); $*p<0.05$.

Conclusions

The CoM appeared to be more locally stable than the feet during gait, in adults and children, meaning that the CoM is less sensitive to perturbations. However, the CoM appeared to be orbitally less stable than the feet, meaning that the CoM had more difficulties to return to a stable movement once perturbed. The feet seem to be able of quick response to perturbation, by returning more efficiently towards a stable dynamic movement than the CoM. This might be interpreted as a strategy of the neuro-muscular system to avoid perturbation at the CoM level. Interestingly, children adopted an over-stabilization of the CoM in all directions to perform gait, which can be related to the degrees of freedom freezing strategy evocated by Bernstein [3].

Keywords: *nonlinear gait analysis, global analysis, gait function*

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AUTOMATED CLASSIFICATION OF GAIT DISORDERS USING SPATIO-TEMPORAL DATA

C. Pradhan, T. Brandt, K. Jahn, R. Schniepp

German Center for Vertigo and Balance Disorders, DSGZ, University of Munich, Munich, Germany
Email: cauchypradhan@gmail.com

Introduction

While conventional gait analysis may provide a quick overview of gait performance, it often fails to distinguish patients with different pathologies. The reasons have been the huge amounts of generated data, which are difficult to interpret, as well as the absence of specific analysis criteria for pathological gait patterns [1, 2]. The automated systems not only provide a class label useful for diagnostic purposes, but also enable clinicians to identify and understand important gait variables unique to individual clinical conditions [3]. This study aims to determine the accuracy of diagnoses of (oto-) neurological gait disorders using different types of automated pattern recognition techniques.

Methods

Clinically confirmed cases of phobic postural vertigo (N=30), cerebellar ataxia (N=30), progressive supranuclear palsy (N=30), bilateral vestibulopathy (N=30), as well as healthy subjects (N=30) were recruited for the study. Eight measurements with 136 variables using a GAITRite® sensor carpet were obtained from each subject. Subjects were randomly divided into two groups (training cases and validation cases). Sensitivity and specificity of k-nearest neighbor (KNN), naive-bayes classifier (NB), artificial neural network (ANN) and support vector machine (SVM) in classifying the validation cases were calculated.

Results

ANN and SVM had the highest overall sensitivity with 90.6% and 92% respectively, followed by NB (76%) and KNN (73.3%). SVM and ANN showed high false negative rates for bilateral vestibulopathy cases (20% and 26%); while KNN and NB had high false negative rates for progressive supranuclear palsy cases (76.7% and 40%).

Conclusions

Automated pattern recognition systems are able to identify pathological gait patterns and establish clinical diagnosis with good accuracy. SVM and ANN in particular differentiate gait patterns of several distinct oto-neurological disorders of gait with high sensitivity and specificity compared to KNN and NB. Both SVM and ANN appear to be a reliable diagnostic and management tool for disorders of gait.

Keywords: *neurological disorders of gait, pattern recognition, GAITRite, k-nearest neighbor (KNN), naive-bayes classifier (NB), artificial neural networks (ANN), support vector machines (SVM)*

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GENDER-RELATED DIFFERENCES ON BALANCE: DANCERS AND GENERAL POPULATION

[1]**M. Prochazkova**, [1]Z. Svoboda, [1]L. Tepla, [1]M. Blazkova, [2]E. Zemkova, [1]M. Janura

[1]*Faculty of Physical Culture, Palacky University, Olomouc, Czech Republic*
[2]*Faculty of Physical Education and Sports, Comenius University in Bratislava, Bratislava, Slovakia*
Email: maky.prochazkova@seznam.cz

Introduction
Postural stability is crucial in maintaining body balance not only during upright stance but also during locomotion and sports activities [1]. The purpose of this study was to investigate whether any gender differences exist in balance performance during standing posture in elite athletes and general population.

Methods
Fifty-five healthy volunteers (26 ballet dancers: 13 males (age 23.7±4.0 years), 13 females (age 26.0±4.2 years); and 29 general population subjects: 13 males (age 23.5±1.6 years), 16 females (age 24.9±2.6 years)) participated in the study. Postural stability was tested in bipedal stance (BS) – eyes opened (EO), eyes closed (EC), quiet standing (QS) and single leg stance (SLS) – EO, EC, on the foam (P), after 10 turns (T). The data were obtained using a two force plates (Kistler Instrumente AG, Winterthur, Switzerland). For statistical comparison (STATISTICA, Version 12.0, StatSoft, Inc.) the Fisher's LSD post-hoc test ($p<0.05$) was applied.

Results
The results showed significantly higher ($p=0.013$) values of COP standard deviation in mediolateral (ML) direction in male dancers in comparison with female dancers during BS EC. We found significantly faster ($p<0.05$) mean velocity of COP displacement in ML direction and total velocity of COP displacement in men than in women during SLS EO in both observed groups. During SLS EC and SLS T there were significantly higher ($p<0.05$) values in all observed parameters in men in comparison with women of general population. In dancers group during SLS EC, SLS P and SLS T the velocity of COP displacement (in ML, anteroposterior (AP) direction and total velocity) was significantly faster ($p<0.05$) in male than in female.

Conclusions
The results of the present study revealed significant gender-related differences on balance, in both observed groups. This could be due to anthropometric factors (lower COM in females) [2], as well as the habit of using high-heeled shoes (women general population) [3] and dancing in pointe shoes (male dancers) represent small base of support. These shoes put women at risk of postural more demanding situations than men. Therefore, we can conclude that there is the gender-specific effect on the COP displacement and velocity in our study that is why for the future research it is important to divide research's groups according to gender.

Keywords: *male, female, centre of pressure, bipedal stance, single leg stance*

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RELIABILITY OF ASSESSING TRUNK MOTOR CONTROL USING POSITION AND FORCE TRACKING AND STABILIZATION TASKS

N.P. Reeves, J.M. Popovich, Jr., M.C. Priess, J. Cholewicki, J. Choi, C.J. Radcliffe

Michigan State University, East Lansing, USA
Email: reevesn@msu.edu

Introduction

Researchers are applying system-based methods to study human movement, including trunk motor control [1-3]. For these methods to be useful, they must reliably characterize motor control. Therefore, the goal of this study was to quantify the between-day reliability of a set of trunk motor control tasks.

Methods

Ten healthy subjects performed six tasks, involving tracking and stabilizing of trunk angular position in the sagittal plane, and trunk flexion and extension force. For tracking tasks, subjects were instructed to keep either their trunk position (position tracking) or force (force tracking), denoted by *y(t)* on the time-varying, pseudorandom reference signal *r(t)* (Fig. 1). For stabilization tasks, pseudorandom displacement disturbances *d(t)* were applied to the pelvis using a robotic platform. Subjects were instructed to keep either their trunk position upright (position stabilization) or trunk force constant (force stabilization) while disturbances *d(t)* were applied. Trunk motor control was assessed for each task on two days, separated by a minimum of 24 hours. Trunk motor control was assessed using time and frequency domain analyses. The root mean square measure was used to quantify error (*e(t)=r(t)-y(t)*) in the time domain. Accuracy was also assessed in the frequency domain using the frequency response of the error/input ratio (*e(f)/r(f)* for tracking and *e(f)/d(e)* for stabilization). Frequency domain error represents the mean error signal energy over the passband region of 0.1-1.66 Hz for tracking tasks and 0.5-2.9 Hz for stabilization tasks. The between-day reliability for time and frequency domain error was quantified with intra-class correlation coefficients (*ICC)*, which was used to calculate the standard error of measurement (*SEM)*.

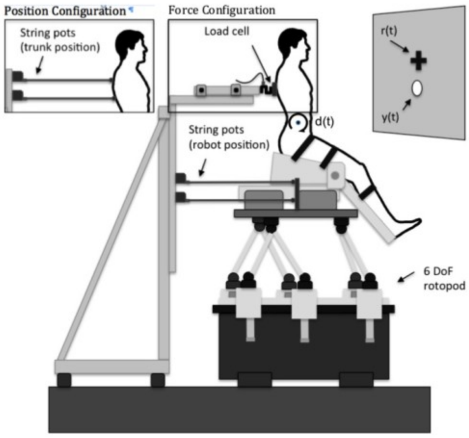

Figure 1 Experimental set-up for trunk position and force tracking and stabilization.

Results

The between-day reliability of time and frequency domain error were excellent (ICC > 0.80, see Table 1). SEM was typically better for frequency than time domain error, with the exception of extension force tracking.

Table 1 *Between-day reliability (ICC(3,k)) for the trunk motor control tasks. The 95% confidence intervals (CI) and SEM are presented in parentheses.*

Task	Time domain error	Frequency domain error
1. Position tracking	0.80 (CI 0.18-0.95, SEM 0.04)	0.80 (CI 0.18-0.95, SEM <0.01)
2. Position stabilization	0.87 (CI 0.49-0.97, SEM 0.07)	0.86 (CI 0.44-0.97, SEM <0.01)
3. Flexion force tracking	0.99 (CI 0.98-1.00, SEM 0.20)	0.99 (CI 0.97-1.00, SEM 0.10)
4. Flexion force stabilization	0.97 (CI 0.86-0.99, SEM 0.18)	0.98 (CI 0.91-0.99, SEM <0.01)
5. Extension force tracking	1.00 (CI 0.99-1.00, SEM 0.44)	1.00 (CI 0.98-1.00, SEM 0.50)
6. Extension force stabilization	0.90 (CI 0.59-0.98, SEM 0.56)	0.95 (CI 0.81-0.99, SEM 0.02)

Conclusions

Results support the notion that trunk motor control can be reliably assessed with position and force tracking and stabilization tasks. In the future, these tests will be applied to investigate changes in trunk motor control that may result from back pain and disability.

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AGE EFFECTS ON MEDIOLATERAL BALANCE CONTROL

[1]L.E. Cofré Lizama, [1]M. Pijnappels, [1]G.S. Faber, [2]**N.P. Reeves**, [3]S.M. Verschueren, [1]J.H. van Dieën

[1]VU University Amsterdam, Amsterdam, The Netherlands
[2]Michigan State University, East Lansing, USA
[3] Katholieke Universiteit Leuven, Leuven, Belgium
Email: reevesn@msu.edu

Introduction

Age-related balance impairments, particularly in mediolateral direction are associated with falls [1]. Unfortunately, many clinical balance tests are not sensitive to detect early stages of impairment [2]. The goal of this study was to determine if Center-of-Mass (CoM) tracking could detect early balance impairments associated with aging. We hypothesized that older adults would have slower balance control than younger adults. Also, the reliability of CoM tracking performance was assessed.

Methods

Balance control of 19 younger (26±3 yrs) and 19 older, "fit" (72±5 yrs) adults was compared. A motion capture system along with an anthropometric model was used to calculate CoM (Fig.1). CoM was displayed as a red circle on a screen in front of the subject. Also displayed was a white circle, which represented a target to be tracked. Subjects were asked to track predictable and unpredictable target moving at increasing frequencies with their CoM by shifting their weight side to side. Gain (amplitude difference) and phase-shift (response delay) between the CoM and target in the frequency domain were used to assess CoM tracking performance. More specifically, the frequencies at which gain and phase-shift dropped below a predefined threshold (0.5 and -90°, respectively) were used to quantify the speed of balance control. Thirteen older and all young adults were reassessed 7 days later to determine the reliability of CoM tracking performance. Older adults were also assessed with common clinical balance tests and conventional posturography.

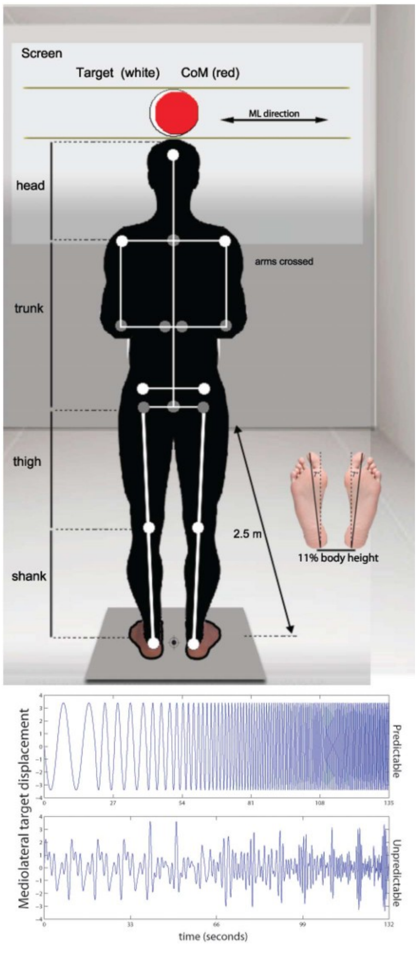

Figure 1 Subjects tracked a moving target (white circle) with their Center-of-Mass (CoM - red circle) by shifting their weight sideways. Both predictable (top) and unpredictable (bottom) target trajectories were used

Results

CoM tracking performance showed good to excellent reliability in both groups. Gain and phase-shift dropped below threshold at lower frequencies in the older adults versus younger, indicating that older adults had slower balance control. No balance impairment was found in the older adults with common clinical balance tests. Also, no differences between younger versus older adults were found using conventional posturography.

Conclusions

With age, balance control becomes slower, which may explain the insufficient weight shifting leading to falls in the elderly [3]. CoM tracking is sensitive to early balance impairments that are not detectable with common clinical balance tests or conventional posturography.

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BODY ORIENTATION ILLUSIONS AND VESTIBULAR REFLEXES REVEAL A DISSOCIATION OF PROPRIOCEPTION FOR PERCEPTION VERSUS ACTION

[1]**R.F. Reynolds**, [2]C.F. Osler

[1]University of Birmingham, Birmingham, UK
[2]University of Derby, Derby, UK
Email: r.f.reynolds@bham.ac.uk

Introduction

Vestibular signals must be interpreted in the context of head position to produce useful motor output. This requires an accurate estimate of head orientation with respect to the body. Consistent with this principle, previous research has shown that during illusions of neck proprioception, the direction of the vestibular-evoked sway response is aligned to the illusory, not veridical, head orientation [1]. Here we re-examine this finding to determine if proprioceptive estimates used for perception and action can be dissociated under certain circumstances.

Methods

We evoked proprioceptive illusions of head-on-foot orientation using two very different methods [2]. The *passive* intervention involved a period of static body twist, whereby subjects stood against a stationary support for 30 minutes with their feet rotated by 54±6 deg with respect to the upper trunk. The *active* intervention simply involved walking on a rotating treadmill for 30 minutes [3]. Galvanic vestibular stimulation (GVS; 3 s; 1.5 mA) was used to determine the directional accuracy of vestibular-evoked sway responses immediately before and after these interventions. Sway direction was measured from the peak ground reaction force vector 180-400 ms post-stimulus (Kistler 9281B). Head orientation was measured using a Polhemus Fastrak sensor.

Results

Both types of adaptation (stepping & static twist) produced similar proprioceptive illusions when blindfolded subjects attempted to stand straight with body segments aligned. Although they perceived themselves to be facing directly forwards, head yaw was shifted by 10-15 degrees (Fig. 1A, Fig. 1B). However, the GVS response was affected differently. Following passive twist, GVS-evoked sway was appropriate for *illusory* head position (i.e. directed through the perceived inter-aural line; see Fig. 1A). In contrast, following rotary stepping, sway direction was appropriate for *actual* head position (Fig. 1B).

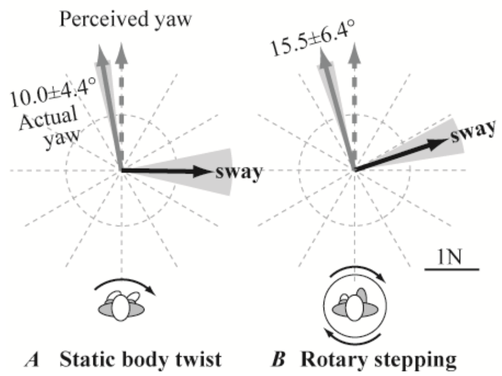

Figure 1 Head yaw orientation and sway direction following the two types of adaptation. Perceived head orientation is always straight-ahead, as depicted by the dashed grey arrow at 0 degrees. Actual head orientation is represented by the solid grey arrow. GVS-evoked sway direction is represented by the solid black arrow. Grey bars depict ±95% confidence limits of angular data. Under normal circumstances, sway direction should be orthogonal to head yaw. This is true for B, but not A, as evidenced by the confidence limits.

Conclusions

Static body twist altered the direction of the GVS-evoked response in concert with the illusion, similar to Gurfinkel et al. [1]. This contrasted with rotary stepping, where vestibular feedback was accurately coupled to head orientation *despite* the illusion. This suggests two dissociable estimates of body proprioception can co-exist in the central nervous system, one for perception and another for action.

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CHRONICAL INSTABILITY OF UPRIGHT STANCE IN SENIOR PATIENTS

[1,2]**M. Saling**, [2,3]M. Kucharik, [1]M. Krivosik, [4]J. Pucik

[1]2nd Department of Neurology, Faculty of Medicine, Comenius University and University Hospital, Bratislava, Slovakia
[2]Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia
[3]National Institute of Cardiovascular Diseases, Bratislava, Slovakia
[4]Slovak University of Technology in Bratislava, Bratislava, Slovakia
Email: marian.salingg@gmail.com

Introduction
Chronical disorders of upright stance are very common in senior patients and strongly influence their quality of life. The causes of disequilibrium can be very different and often present a challenge in diagnostics. The aim of the presented work is to examine the usefulness of static posturography and questionnaire evaluation of postural instability in patients with chronic disequilibrium.

Methods
In years 2013-2014, we examined 230 senior patients (over age of 65 years). We performed static posturography with sensory tests. Prior to posturography, they filled in questionnaire [1] regarding the posture stability and overall status with emphasis on symptoms and diseases which may manifest with stance and gait disorders. In recordings, the velocity amplitude of body sways, total area, as well as frequency analysis were evaluated.

Results
Posturographic tests were able to quantify the extent of instability of patients and also were able to define the basic characteristics of chronic instability. Patients with disorders of the somatosensory system (i.e. polyneuropathy) showed the increased velocity of body sways and increase of frequencies above sways points 1 Hz in the antero-posterior direction. Patients with diffuse (brain) white-matter lesions were characterized predominantly with vascular increased body sways amplitude and with more pronounced response to sensory stimulation. Patients with vestibular disorder have often showed the asymmetric response to galvanic vestibular stimulation and they were unable to maintain a stance on soft (foam) platform.

Conclusions
Disorders of upright stance are very frequent in senior patients and usually several factors contribute to the impairments of stance. Static posturography is suitable test to detect dominating cause of chronic instability in senior patients. Extensive questionnaire used prior to measurement provided additional information about the influence (and relevance) of stance disorders on daily living activities of senior patients.

Keywords: *upright posture, seniors*

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THE EFFECT OF COMPLIANT SUPPORT SURFACES ON SENSORY REWEIGHTING OF PROPRIOCEPTIVE INFORMATION IN HUMAN BALANCE CONTROL

[1]**I.M. Schut**, [2]D. Engelhart, [1]J.H. Pasma, [2]R.G.K.M. Aarts, [1,2]H. van der Kooij, [1,2]A.C. Schouten

[1]Department of Biomechanical Engineering, Delft University of Technology, Delft, The Netherlands
[2]Laboratory of Biomechanical Engineering, Institute for Biomedical Technology and Technical Medicine (MIRA), University of Twente, Enschede, The Netherlands
Email: i.m.schut@tudelft.nl

Introduction
To maintain an upright posture and prevent falling, balance control involves the complex contribution of neural, muscular and sensory systems. Information from the sensory systems is combined based on their reliability according to a dynamically weighting process, i.e. sensory reweighting [1]. Elderly with impaired balance, often undergo functional balance training on compliant surfaces, such as foam mats. However, the driving mechanism of these compliant surfaces and the effect on sensory reweighting remains unclear. In this study, we investigated the effect of compliant surfaces on sensory reweighting of proprioceptive information in balance control using system identification techniques.

Methods
In this study, 11 healthy subjects (age 20-30 years, 8 women) were asked to maintain their balance while proprioceptive information was perturbed by continuous rotations of the support surface. Multisine torque disturbances containing frequencies in the range of 0.05-10 Hz were applied on the support surface resulting in desired support surface angles. In 9 trials, the level of the compliance of the support surface and the desired support surface angle were varied to investigate both the effect of compliance and support surface rotation amplitudes. With the use of system identification techniques, the response of the ankle torques to the support surface angles was determined and represented by frequency response functions (FRFs). Lower frequency gains (LFGs) were calculated by averaging the gains in a lower frequency window (0.05-0.25 Hz) representing the proprioceptive weight.

Results
Results showed that an increase in support surface angle leads to a decrease in LFG indicating less use of proprioceptive information with increasing support surface angle. There was no significant effect of the compliance of the support surface on the LFG.

Conclusions
This study demonstrated that sensory reweighting was influenced by the support surface angle and not by the support surface compliance. Therefore, during standing on a foam mat the driving factor of sensory reweighting is the increased support surface angle due to the compliance and not the compliance of the support surface itself. Adjusting the compliance of the foam mat to the patients characteristics (e.g. mass and length) may increase the effectiveness of balance training.

Keywords: *human balance control, proprioception, sensory reweighting, system identification, frequency response function, foam mats*

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EFFECT OF SURGICAL RECONSTRUCTION OF ANTERIOR CRUCIATE LIGAMENT AND CONSECUTIVE REHABILITATION OF SELECTED POSTURAL STABILITY ASPECTS

[1]**H. Šingliarová**, [2,3]P. Valkovič, [3]Z. Hirjaková, [3]F. Hlavačka

[1]*Department of Rehabilitation, University Hospital, Bratislava, Slovak Republic*
[2]*2nd Department of Neurology, Comenius University, Bratislava, Slovak Republic*
[3]*Institute of Normal and Pathological Physiology, Slovak Academy of Sciences, Bratislava, Slovakia*
Email: singliarka@gmail.com

Introduction

Currently, the injury of *ligamentum cruciatum anterius* (ACL) of knee is one of the most studied ligaments traumas. Its consequences lead to instability of the knee joint and accelerating degenerative changes. Despite the progress in surgical and conservative treatment, the outcome is not always sufficient. Many patients do not return to the previous functional and sport level. The aim of the study was to obtain new knowledge about postural stability of patients with ACL before and after the reconstructive surgery and rehabilitation focused on somatosensory improvement with the components of proprioceptive training, dynamic neuromuscular stabilization (DNS) and neurocognitive rehabilitation.

Methods

Seventeen subjects (15 men, 2 women; mean age 30.5 ± 8.7 years) with the ACL lesion participated in the study. The average time from the injury to surgery was 27.7 months. The reconstruction of ACL was made by BTB (bone-tendon-bone) graft from *ligamentum patellae*. Clinical HOP test, static posturography and vibrations of lower leg muscles were used to measure the balance control and lateral differences between legs: 1) preoperative, 2) six weeks after the surgery, and 3) three months after the surgery and focused rehabilitation. The balance control was measured during quiet stance in 4 conditions: stance on a firm / foam surface with eyes open / closed. Five parameters were evaluated: amplitude in anterior-posterior (Ay) and medial-lateral (Ax) directions, velocity in anterior-posterior (Vy) and medial-lateral (Vx) directions and line integral (LI). Vibrations of lower leg muscles *m. triceps surae* (TS), *m. quadriceps femoris* (Q) and simultaneous vibration of *m. quadriceps femoris* and hamstrings (QH) were provided and quantified by the shift and slope of CoP displacements in anterior-posterior direction.

Results

Preoperative, lateral differences between legs were observed in HOP test with reduced length of the jump on the leg with ACL lesion. An impaired postural orientation was documented by greater CoP shift in the condition with vibration QH and by slower reaction to vibration TS on the injured leg. The vibration Q did not induce significant changes. Reconstructive surgery temporarily worsened postural stability parameters 6 weeks after the surgery comparing to preoperative measurement, documented by increased postural parameters (Ax, Vy, LI) during the stance on firm surface with eyes open (EO). During vibration TS, the CoP shift was reduced on the leg with ACL reconstruction comparing to preoperative measurement. In HOP test, the length of the jump on the ACL leg was reduced. Three months after the surgery and rehabilitation focused on somatosensory, we observed significant improvement of postural stability comparing to the measurement 6 weeks after surgery. During the stance on foam surface with eyes closed (FEC) a decrease of postural parameters (Ax, Vx, LI) was documented. However, reactions to the vibrations of the leg with ACL reconstruction showed a tendency to upturn; they did not reach preoperative level. The improvement was also documented in functional Hop test on both legs.

Conclusions

According to these results we can conclude that proprioceptive deficit after ACL injury can be documented not only by clinical tests, but also by static posturography and vibrations of lower leg muscles. Preoperative deficit of proprioception worsened 6 weeks after reconstruction with a tendency to upturn 3 months after the reconstruction. The rehabilitation focused on somatosensory function helped to improve sensory integration, postural stabilization and function of injured knee joint.

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VALIDITY OF A SENSOR-BASED TOOL FOR TRUNK MOBILITY ASSESSMENT

[1]**M. Smondrk**, [2]S. Mellone, [1]J. Krohova, [2]L. Chiari

[1]*Department of Cybernetics and Biomedical Engineering, Technical University of Ostrava, Ostrava, Czech Republic*
[2]*Department of Electrical, Electronic, and Information Engineering, University of Bologna, Bologna, Italy*
Email: maros.smondrk@vsb.cz

Introduction
The treatment of trunk movement dysfunction requires significant health care resources and involves a substantial long term physical therapy and rehabilitation. There are many disability scales developed for functional assessment following rehabilitation, as well as motion capture systems capable of quantifying human body kinematics with high accuracy, but their constraints limit their usage in clinical practice. A sound alternative to monitoring patient's motor performance during the rehabilitation process is represented by inertial and magnetic sensors (MIMU). The aim of this work is to investigate the validity of a MIMU-based tool for the assessment of trunk mobility.

Methods
Twenty healthy young adults (27.5 ± 3 years old, range 23 to 35) volunteered in this study. The experimental assessment protocol of trunk mobility includes nine bending movements performed while seated: three in the forward direction, three on the left side, and three on the right side. Participants performed the assessment protocol while seated on a chair without backrest and armrest; arms were folded on the chest and the range of trunk motion was approximately 30 degrees from upright sitting posture. Two custom-made planar rigid clusters carrying four markers and one MIMU each were attached to the skin overlying the spinous processes of the lumbar (L4) and cervical (C7) spine. The absolute orientation of each spinal segment and their relative orientation were measured as Euler Angles: yaw (rotation about the vertical axis), pitch (rotation about the medio-lateral axis), and roll (rotation about the anterior-posterior axis). Agreement between the orientation estimation obtained with the stereophotogrammetric system (considered as the gold standard) and the MIMU units was quantified by means of the root mean square error (RMSE) and the Bland-Altman Limits of Agreement (LoA).

Results
Best results were obtained for the lumbar segment with a RMSE value of 0.91° and 0.87° for the pitch and roll, respectively; LoA were [-1.59°, 1.92°] for the pitch and [-1.86°, 1.48°] for the roll. For the cervical segment a RMSE of 1.72° and 1.70° were obtained for the pitch and roll, respectively; LoA were [-2.48°, 3.77°] for the pitch and [-1.73°, 3.70°] for the roll. Lower agreement has been observed for the yaw with a RMSE value of 2.08° and [-4.54°, 3.09°] LoA for the cervical segment and a RMSE value of 5.69° and [-12.45°, 8.39°] LoA for the lumbar segment. Considering the relative orientation of the two segments of the spine we obtained a RMSE value of 2.46° and 2.25° for the pitch and roll, respectively; LoA were [-3.93°, 5.33°] for the pitch and [-2.41°, 4.91°] for the roll. Again the relative orientation about the vertical axis was the condition with the lower agreement with a RMSE value of 6.15° and [-10.39°, 13.12°] LoA.

Conclusions
The MIMU-based sensing technology provides an accurate monitoring of the trunk orientation in dynamic conditions when considering pitch and roll; yaw angles showed instead a lower accuracy because of the drift induced by electromagnetic disturbances affecting the magnetometer. The accuracy of the used MIMU for the estimate of pitch and roll was even higher than the typical values reported by leading MIMU-based systems manufacturers. In perspective, MIMU-based assessment tools could be capable to monitor patient's motor performance during the rehabilitation process and to objectively compare different rehabilitation approaches.

Keywords: *magnetic and inertial measurement unit, stereophotogrammetric system, trunk movement*

AGING EFFECTS ON POSTURAL TRACKING OF COMPLEX VISUAL MOTIONS

[1]**H. Sotirakis**, [2]N. Kyvelidou, [2]N. Stergiou, [1]V. Hatzitaki

[1]*School of Physical Education and Sport Science, Aristotle University of Thessaloniki, Greece*
[2]*Biomechanics Research Building, University of Nebraska at Omaha, United States*
Email: sotiraki@phed.auth.gr

Introduction

Perceptual, cognitive and motor decline in old age is accompanied by a gradual loss of the ability to effectively integrate the available sensory inputs for closed loop control of posture and gait. Practicing visually guided postural sway improves the link between perception and action in old age [1], nevertheless, use of predictable visual target cues leads to open loop control and loss of visuo-motor adaptability. We have recently shown that healthy young adults entrain their posture and gaze to complex visual motions similarly well as they entrain to periodic ones [2]. In this study, we asked how well healthy old and young adults can track visual target cues of varying degree of complexity during whole-body swaying in the frontal plane.

Methods

Ten healthy young (25.63±3.66 yrs) and 10 old (72.54±4.52 yrs) participants performed a weight shifting task while tracking a horizontally moving target that was displayed on a TV screen (LG 60LA620S-ZA, 120x80 cm, stimulus motion update 50 Hz) located at a distance of 1.5 m in front of them, at eye level. Postural sway in the form of normalized body weight distribution between two force platforms (Balance Plate 6501, Bertec) was sampled (100 Hz) via an A/D board and feedback to the subject in real-time. Participants performed 30 weight shifting cycles in 120 s while tracking one of three target motions: a complex (Lorenz attractor), a noisy (Lorenz Surrogate) and a periodic (sine) target motion. Force-target coupling was quantified in the spectral coherence, gain and phase calculated over a 0-1 Hz frequency band. The effect of target complexity and age were analyzed employing 3x2 repeated measures ANOVA.

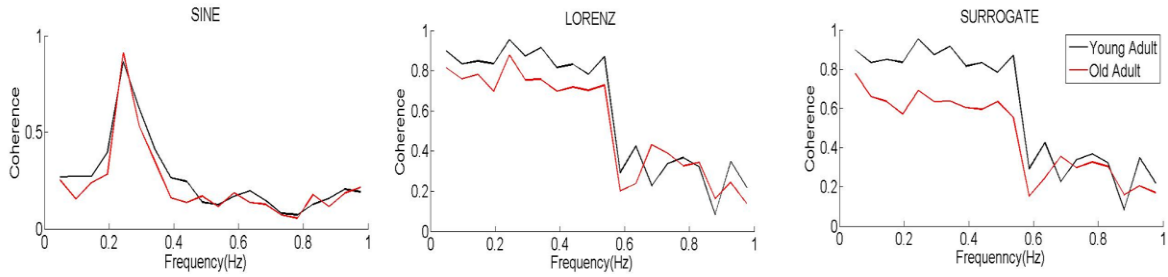

Figure 1 Averaged force-target coherence for the young (black line) and old (red line) group in the 0 to 1 Hz frequency band.

Results

Force-target coherence peaked at 0.24 Hz when tracking the sine target motion, was high between 0 and 0.55 Hz for the Lorenz attractor and significantly less than 1 when tracking the noise signal (Fig. 1). Coherence at 0.24 Hz was similarly high for the periodic and complex but significantly lower for the noise target cue [$F_{(2,38)}$=16.54, p<.001]. Force-target coherence was similar between age groups when tracking the periodic target motion but significantly lower for old adults when tracking the complex and noise targets [$F(_{1,20})$=4.29, p<.05]. Similar were the findings for the force-target phase and gain.

Conclusions

Results confirmed that a less predictable (complex) visual target motion can be tracked similarly well as a predictable (periodic) one during whole body postural tracking. Old adults however showed decreased force-target coupling when tracking the complex visual motions. Whether less predictable visual cues provide a better training stimulus for improving visuo-motor adaptability in old age requires further investigation.

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FUNCTIONAL REACH IN INTERPERSONAL HAPTIC LIGHT TOUCH INTERACTIONS FOR BALANCE SUPPORT

S. Steinl, L. Johannsen

Department of Sport and Health Sciences, München, Germany
Email: saskia.steinl@tum.de

Introduction

Touch is the first of our senses to develop, and it provides us with our most fundamental means of contact with the external world [1]. Touch can be seen as a tool for social information and human-to-human information, which conveys features of individuals or their interactions that have potential bearing on future interactions, and attendant mental and emotional states of interaction [2]. Balance serves as a reference frame for perception and action with respect to the external world. It is not only required for maintenance of an upright posture, but also during movement. The functional reach task [3] challenges control of body sway as the body's Centre-of-Mass (CoM) is brought into close proximity of its physical limits of stability. Precise control of sway is essential in this critical state as the likelihood of loss of balance increases proportionally to any increase in reach distance. Functional reach performance is likely to depend on a participant's balancing self-confidence as well.

Methods

In this study we aimed to test the effect of light interpersonal touch on body sway as well as sway coordination between a contact receiver performing a goal-directed maximum forward reach task and a contact provider. Four participant pairs (n=8) have so far been tested. To measure body sway and interpersonal coordination motion capturing was used according to a biomechanical model. Four cameras (120 Hz) recorded the trials. In addition to that each of the participants stood on force platforms. During the whole experiment the agent had closed the eyes, whilst the provider varied between touch and no touch respectively full, peripheric and no vision respectively light or heavy object. Ultimately summing up for 24 conditions/ trials each lasting for 25 seconds. Our presentation will report preliminary results.

Results

Direct visual observation of the receiver's goal-directed reaching performance by the provider would result in the tightest coupling between both agents in terms of cross-coherence of sway. Agent and provider seem to have the best balance control in this condition.

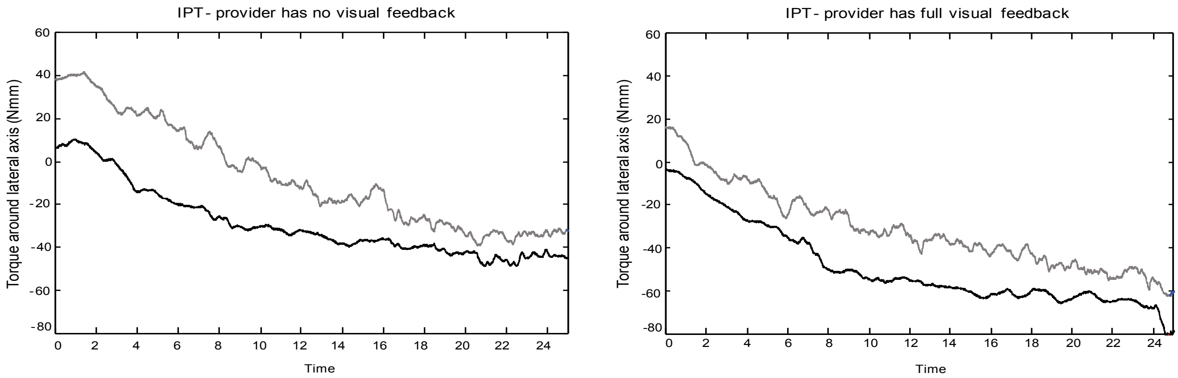

Figure 1 Torque behavior of agent (grey) and touch provider (black) in the condition of no vision of the provider (left) and full vision of the provider (right).

Conclusions

Regarding the different vision conditions in terms of balance instability and interpersonal coordination the light touch/full vision condition seems to have the best output. The combination of haptic and visual feedback seems to support the sway synchronization the most.

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RELATIONSHIP BETWEEN WALKING ACTIVITY AND POSTURAL STABILITY IN MIDDLE-AGE WOMEN

[1]**Z. Svoboda**, [1]L. Bizovska, [1]R. Cuberek, [2]E. Zemkova,[1] M. Janura

[1]Faculty of Physical Culture, Palacky University, Olomouc, Czech Republic
[2]Faculty of Physical Education and Sports, Comenius University in Bratislava, Bratislava, Slovakia
Email: zdenek.svoboda@upol.cz

Introduction

The effect of physical activity (PA) interventions including specific balance training often results in improvement in postural stability, however relationship between non-specific physical activity interventions (e.g. walking activity) and postural stability have not been sufficiently studied yet. The aims of this study were to describe relationship between walking activity and postural stability and to observe the effect of walking intervention on postural stability in middle-age women.

Methods

The study was performed as a randomized control trial. Participants were randomly divided to intervention (n=67, age 55.9 ± 3.9 years, body height 163.5 ± 5.5 cm, body weight 69.9 ± 13.0 kg) and control group (n=54, age 57.9 ± 5.7 years, body height 163.4 ± 5.0 cm, body weight 74.3 ± 15.4 kg). The walking activity intervention was a walking programme defined as an increase in habitual PA by brisk walking to or from work of 30 to 35 minutes or by a walking activity of an identical duration throughout the day. The amount of walking activity was monitored by recording step counts before (one week) and throughout intervention (10 weeks). Step counts were measured using the Yamax DigiWalker 700 SW pedometer (Yamax Co., Yasama Corp., Tokyo, Japan). Postural sways (centre of pressure velocities) were measured by force plate (type: 9286 AA, Kistler Instrumente, Wintherthur, Switzerland) during 30 s natural standing with open and closed eyes (two trials for each condition). The data was filtered using a 4th order low-pass filter Butterworth (frequency 7 Hz). Relationship between walking activity and centre of pressure (COP) velocities was determined by Spearman's correlation. The effect of intervention on COP velocities was determined by ANOVA and Fisher's post-hoc test.

Results

Significant correlations were found between walking activity before intervention and COP velocity in anterior-posterior direction through both measured groups during open and closed eyes conditions ($r = 0.24$). Similarly walking activity during intervention correlated with COP velocity in anterior-posterior direction ($r = 0.26$) and additionally also in total COP velocities ($r = 0.19$) in both open and closed eyes conditions. No significant relationship was found between changes in walking activity and changes in COP velocities. Comparison of postural sways before and after interventions showed only one significant difference in intervention group. COP velocity in medial-lateral direction significantly decreased after intervention ($p = 0.009$). Postural sways in control group were without significant differences.

Conclusions

The results of our study suggest relationship between walking activity and fall risk. Subjects with decreased walking activity are characterized by increased postural sway in anterior-posterior direction, which is considered as variable related to fall risk. The effect of 10 week walking intervention on postural stability seems to be relatively small.

Acknowledgements: The study was supported by a research grant from the Czech Science Foundation (13-32105S) and the grant of the Czech Ministry of Education, Youth and Sports and Slovak Research and Development Agency (SK-CZ-2013-0131, 7AMB14SK073).

Dynamic Time Warping in assessment of performed training

[1,2]**A. Świtoński**, [2]H. Josiński, [2]A. Szczęsna, [3]R. Mucha, [1]K. Wojciechowski

[1]Polish-Japanese Academy of Information Technology, Bytom, Poland
[2]Silesian University of Technology, Gliwice, Poland
[3]Medical University of Silesia, Bytom, Poland
Email: aswitonski@pjwstk.edu.pl

Introduction
The abstract presents the concept of Virtual Physiotherapist (VPh) which supports rehabilitation in home environment or in a medical facility. The VPh consists of acquisition, database and software components. The motion data of patient training and exemplary exercises performed by a skilled physiotherapist are captured and stored in a database. The motion capture technique based on the IMU sensors will be applied. It gives possibility to create any configuration of the sensors in respect to a specified kinematical chain of a human body and performed exercises. The main functionality of a software is related to an online feedback activated in case of remarkable mistakes of patient training. To determine the mistakes a comparative analysis of patient and physiotherapist motion data is carried out. Thus, the VPh is flexible and not limited to only specified motion disorders. To create a new training plan, the database has to be extended with data of new exercises. What is more, the exercises can form a hierarchy (from the easiest to the most difficult ones) with an additional rule based data. It allows to construct a reasoning module, responsible for an adaptive and dynamic selection of subsequent exercises.

Methods
On the basis of our previous works [1, 2] Dynamic Time Warping (DTW) is chosen for aforementioned comparative analysis. It synchronizes motion sequences by matching their time instants with dynamic, monotonic transform of a time domain. DTW requires to calculate a dissimilarity matrix with distances between every pair of poses of considered motion time series. It is used to determine monotonic path with minimal aggregated total distance across pose dissimilarity values. In case of skeleton based motion data the crucial is the choice of proper approach to assess distance between pair of rotations. By default, Euler angles are used to represent skeleton data. In this case classical metrics as for instance Euclidean or Manhattan ones can be utilized. However, much more efficient and compact representation of rotation is given by unit quaternions. The most often used rotation distance functions for unit quaternions are as follows: geodesic or cosine distance calculated on hypersphere S^3 or tangent space based one [1, 2]. As the result, DTW assesses total dissimilarity of compared motions, which corresponds to score evaluating quality of training performed. To point incorrect movements, the warping path representing DTW synchronization is analysed. Its segments with noticeably dissimilar time instants indicate the movements. DTW calculated separately for subsequent skeleton joints allows to assess the improper movements of specified body segments whereas DTW applied to multidimensional time series with data of a complete set of joints - their coordination.

Results and conclusions
Preliminary motion recordings were captured in the Human Motion Laboratory of PJAIT (http://hml.pjwstk.edu.pl). They are related to degenerative diseases of a hip joints, poststroke and Parkinson motion disorders. Similar to VPh working strategy exemplary exercises and ones performed by a trained patients are acquired and they are compared by DTW technique and skilled physiotherapist. In general, DTW determines similar mistakes of training as a human expert. The scale of obtained dissimilarity measures is different for applied rotation distance functions, separate body parts and exercises. An important information is also given by the shape of DTW path, which corresponds to dynamical mapping of the synchronization. What is more, the comparison of time series representing angular velocities and accelerations approximated by differential filtering of time domain was investigated. It detects quite different mistakes of training related to dynamics of movements rather than their ranges and trajectories.

Acknowledgements: The work is supported by The Polish National Centre for Research and Development, the project is named "Virtual physiotherapist".

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RESPONSIVENESS TO SUPPORT SURFACE ROTATIONS PREDICTS BALANCE RECOVERY CAPACITY

[1]**J. van Kordelaar**, [2]D. de Kam, [2]W. van Orsouw, [1]H. van der Kooij, [2]V. Weerdesteyn

[1]Lab. of Biomechanical Engineering, University of Twente, Enschede, The Netherlands
[2]Dept. of Rehabilitation, Radboud University Medical Center, Nijmegen, The Netherlands
Email: j.vankordelaar@utwente.nl

Introduction

Adequate balance recovery responses are essential to prevent loss of balance and falls. To control the torques necessary for keeping the body upright the human balance control system uses proprioceptive, visual and vestibular information. We investigated how neuromuscular control, as well as sensitivity to proprioceptive and visual perturbations, correlated to balance recovery capacity.

Methods

We included 15 healthy young subjects (4 female) with a mean age of 24.8 years (SD: 3.5 years). Balance recovery capacity (stepping threshold) was measured with the Radboud Falls Simulator, i.e. a movable platform on which participants were subjected to platform translations with gradually increasing acceleration [1]. The stepping threshold was defined as the largest platform acceleration (forward and backward) that can be overcome with a feet in place response. In addition, we used the Balance Test Room (BalRoom) to apply continuous visual scene rotations (i.e. visual perturbations), support surface rotations (i.e. proprioceptive perturbations) and force perturbations at the pelvis and shoulder [2]. Frequency response functions were used to estimate the response of the joint torques and segment angles to visual and proprioceptive perturbations and to estimate the response of the joint torques to body segment oscillations due to the force perturbations (i.e. neuromuscular control). Pearson correlation coefficients were used to investigate how body responses at frequencies ≤ 1 Hz were related to stepping thresholds.

Results

Larger sensitivity to proprioceptive perturbations was associated with lower (poorer) stepping thresholds (R = -0.62 — -0.57, p ≤ 0.028, Fig. 1). Stepping thresholds were not significantly related to responses to visual scene rotations and neuromuscular control.

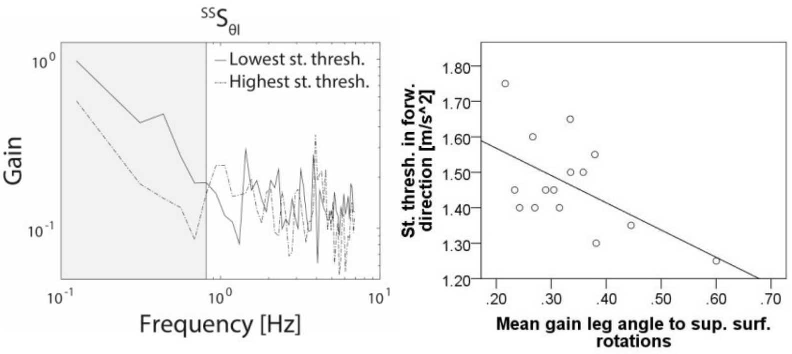

Figure 1 A Gain of the leg angle (θ_l) to the support surface (SS) rotations for the subjects with lowest (1.3 m/s^2, solid line) and highest stepping threshold (1.75 m/s^2, dashed line) in forward direction. Grey area marks frequency range ≤ 1 Hz which was used for statistical analysis. **B** Scatterplot of the relation between the leg angle response to SS rotations and stepping thresholds.

Conclusions

Our findings suggest that increased responsiveness to support surface rotations (i.e. proprioceptive perturbations) predicts reduced balance recovery capacity. Increased responsiveness to proprioceptive perturbations may reflect a reduced reliance on other sensory cues, including vestibular information, which may ultimately have led to reduced balance recovery capacity in our subjects.

Keywords: *balance control, system identification, fall risk*

Acknowledgements: This study was conducted within the BalRoom project, supported by the Dutch Technology Foundation STW, and the EMBalance project, supported by the European Union (FP7-ICT project 610454).

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FUNCTIONAL MUSCULAR COORDINATION UNDERLYING MOVEMENT PATTERN CHANGES

[1]**C.A. Vernooij**, [1]G. Rao, [2,3]D. Perdikis, [2]R. Huys, [2]V.K. Jirsa, [1]J.J. Temprado

[1]Institut des Sciences du Mouvement UMR7287 & CNRS, Marseille, France
[2]Institut de Neurosciences des Systèmes UMR_S1106 & Inserm, Marseille, France
[3]Max Planck Institute for Human Development, Berlin, Germany
Email: carlijn.vernooij@univ-amu.fr

Introduction

The dynamical systems approach addresses Bernstein's degrees of freedom problem by assuming that the neuro-musculo-skeletal system assembles its functional components into temporary regimes to meet task demands. However, little is known about the highly non-linear muscular system in this process. We searched for signatures of a dynamical reorganisation in muscular coordination as measured by EMG and studied if changes in behavioural patterns are accompanied by reorganisations of muscular coordination patterns.

Methods

We used a multi-segment cyclical Fitts' task with changing target width (target distance = 20 cm; index of difficulty ID = 3.3-6.9 bits) to force the right arm to change its behavioural dynamics from a limit-cycle to a fixed-point regime, which was confirmed by phase flow analyses [1]. We measured EMG from 12 arm and shoulder muscles to measure muscular activation. We used PCA to study muscular coordination patterns and, for the first time to our knowledge, functional connectivity dynamics [2] to study variability in EMG.

Results

Phase flow trajectories and kinematic behavioural patterns indicated a transition in behavioural dynamics around ID = 5.1 bits (Fig. 1a). Trajectory variability increased significantly after the transition. In parallel, an associated reorganisation of muscular coordination patterns was found. This was accompanied by significantly increased levels of variability in EMG (Fig. 1b).

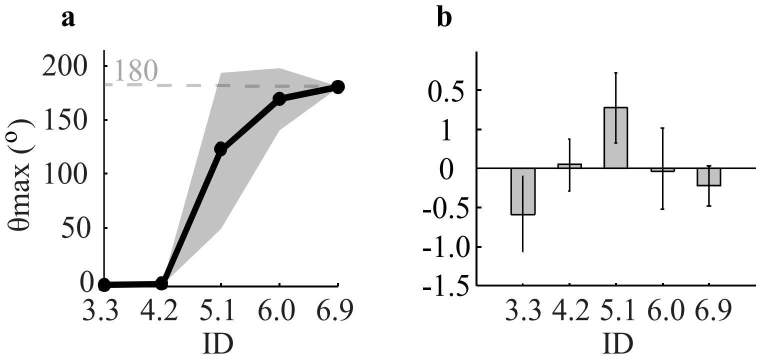

Figure 1 Signatures of phase transition: **a)** Maximum angles of the phase flow trajectories, where θmax ~ 0 indicates limit cycle and θmax ~180 indicates a fixed point; **b)** Variability of EMG signals, where non-overlapping errorbars indicate significant difference.

Conclusions

Our results provide evidence that during Fitts' task, when behaviour undergoes a phase transition from limit-cycle to fixed-point regime, muscular coordination captured by EMG also displays classical signatures of a phase transition, i.e. a reorganisation in muscular coordination patterns accompanied by a peak in EMG variability. This is coherent with studies on walk-to-run transitions [3], and suggests that consistent changes occur in coordination processes across the different levels of description (i.e. brain, behaviour and muscle).

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WALKING MOTION PREDICTABILITY EXPLAINS PHASE- AND SPEED-DEPENDENT MODULATIONS OF SENSORY INPUTS DURING LOCOMOTION

M. Wuehr, R. Schniep, P.R. MacNeilage, S. Glasauer

German Center for Vertigo (DSGZ), University Hospital of Munich, Germany
Email: max.wuehr@med.uni-muenchen.de

Introduction

There is increasing evidence for a phase- and speed-dependent modulation of sensory contributions to postural control during walking [1, 2]. Recently this modulation was explained in terms of a selective suppression of sensory inputs by intrinsic locomotor efference copies observed during animal locomotion [3]. The feasibility of such a feed-forward mechanism should however critically depend on the predictability of head and body motions during locomotion [4].

Methods

Here, we test this hypothesis within the framework of a statistically optimal model [5], in which the relative weight given to the efference copy and sensory inputs depends on the predictability of the walking motion. The walking patterns of 31 healthy subjects (mean age 35.0 ± 2.7 years, 15 female) were recorded on a pressure-sensitive treadmill system while walking at five different speeds (preferred walking speed and 20%, 40%, 70%, 80% of maximal walking speed). Motion predictablity was quantified by calculating the coefficient of determination of the recorded center-of-pressure (CoP) trajectories. We further examined if CoP motion predictability is related to the overall local dynamic stability (LDS) of the walking pattern quantified by the short-term Lyapunov exponent.

Results

CoP motion predictability exhibited phase-dependent alterations within the gait cycle ($p<0.001$) that resemble previously reported phase-dependent modulations of sensory inputs during the gait cycle [6]. In anterior-posterior direction it increased with increasing walking speed whereas it remained almost constant in medio-lateral direction ($p<0.001$) in conformance with previously observed speed-dependent modulations of sensory contributions to walking [1]. Moreover, the degree of predictability significantly correlated with the LDS of walking in anterior-posterior (R=0.74) and medio-lateral (R=0.63) direction.

Conclusions

The here proposed theoretical and evidence-based approach provides a compatible explanation for the phase- and speed-dependent reliance on sensory contributions during walking. It further underpins a tight inverse relation between the relative weight of sensory contributions and the degree of dynamic walking stability. Finally, it gives evidence for hitherto unknown aspects of sensorimotor walking control that can be experimentally verified in future.

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A NOVEL APPROACH ENHANCING BALANCE PERFORMANCE IN A PATIENT WITH SECONDARY DYSTONIA: A CASE STUDY

[1]**F. Yadolahi**, [2]M. Mehrpour

[1]School of Rehabilitation, Physical therapy department, Shahid Beheshti University of Medical sciences, Tehran, Iran
[2]School of Medicine, Neurology department, Iran University of Medical Sciences, Tehran, Iran
Email: fariba.yadolahi@sbmu.ac.ir

Introduction
Dystonia is defined by involuntary, sustained muscle contractions which cause twisting and repetitive movements or abnormal postures. Secondary dystonia can be due to cerebral trauma or hypoxia, such as the basal ganglia and the thalamus infarct. Postural control is an area of critical importance in rehabilitation research. We have developed a new conceptual framework for balance training emphasizing Transcranial direct current stimulation (tDCS), a new and promising method, in a patient with secondary dystonia. We examined the therapeutic potential of tDCS combined with balance training and medication therapy on postural performance in this type of dystonia.

Methods
In this double-blinded-placebo controlled case study, 10 sessions of bihemispheric tDCS was delivered to 25 -year-old female patient suffering from secondary dystonia due to stroke two years ago. The patient received 10 consecutive daily sessions of bihemispheric tDCS (2 mA, 20 min) combined with Biodex balance training and Tetrabenazine. Cathodal stimulation was over primary motor cortex of affected side and anodal stimulation was applied over right dorsolateral prefrontal cortex (DLPFC). Function was assessed by using Fahn-Marsden dystonia Scale and the postural control was quantified by analysis of center of pressure (CoP) traces during quiet standing with eyes open and closed. Time up and go test (TUG), Fahan test and CoP fluctuations was examined before and after treatment.

Results
Results demonstrate significant improvements in weight-bearing symmetry, postural parameters of CoP during quiet stance and TUG test measurements after active tDCS. This study indicates that tDCS - supported therapy improves stability in secondary dystonia when stimulating the affected motor cortex with the cathodal and the unaffected motor cortex with the anodal electrode. These results were closely associated with improved performance in the Fahan test; a widely-used clinical assessment in dystonia.

Conclusions
This is the first report to investigate the effects of an integrated approach using tDCS in balance performance in a patient with secondary dystonia after infarct which may opens up novel perspective for the use of tDCS in balance rehabilitation in dystonia.

Keywords: *tDCS, dystonia, lower limb, balance, rehabilitation*

SELECTED POSTURAL STABILITY PARAMETERS AT SENIOR'S AGE

F. Zahálka, T. Malý, L. Malá, T. Gryc, P. Hráský

Charles University, Faculty of Physical Education and Sports, Prague, Czech Republic
Email: zahalka@ftvs.cuni.cz

Introduction

The aim of the study was observation and comparison of selected parameters of postural stability according to the age at senior's population. The space orientation and sensation of postural stability is realized by interaction between vestibular system, sensory system, visual control and proprioception [1].

Methods

The research group was collected from seniors at age 50-92 years and all of them were participants of "University of the third age". All participants were divided to four groups according to the age (50-60, 60-70, 70-80, 80-90 years), and also divided to the groups according to the gender (men and women). All participants absolved six tests with duration 30 sec (wide standing with open eyes and closed eyes, narrow standing with open eyes and closed eyes, standing on one lower limb – Flamingo test FL). For postural stability measuring, the FootScan system (RScan, Belgium) was used. For evaluation of postural stability, we used selected parameters (anterio-posterior deviation, medio-lateral deviation, total travelled way - TTW of Centre of Pressure, resp. Centre of Forces). Differences between postural parameters with relation to the selected factors were analysed by multiplied analysis of variance (MANOVA) and effect size (Eta square - η_p^2).

Results

The first evaluated parameter was deviation in anterio-posterior and medio-lateral direction. The whole group differences between wide standing position with open and closed eyes in anterio-posterior direction were 8% and 39%, resp. 32% and 36% in narrow standing position. Parameter TTW had difference 16% between open and closed eyes in wide standing position and 13% at narrow standing position. Very interesting results were at standing on one lower limb only. Parameters TTW were very similar between standing on left resp. right lower limb (difference was 6% only). According to group comparison there was found significant effect of age to postural stability ($p<0.01$, $\eta_p^2 = 0.189$). The group of women had better level of postural stability and there were significantly lower values of selected parameters ($p<0.01$, $\eta_p^2 = 0.113$). During tests of standing with open eyes there were found significant differences between gender by help of post-hoc tests (between groups of age 50-60 years, 60-70 years and 70-80 years; $p<0.05$). During tests of standing with closed eyes we found significant differences between gender by help of post-hoc tests (between groups of age 60-70 years and 70-80 years; $p<0.05$). Visual control had significant effect to postural stability ($p<0.01$, $\eta_p^2 = 0.252$).

Conclusions

The study confirmed hypothesis that postural stability decreased during aging [2]. Age of observed group had significant influence on the selected parameters of postural stability at tests with open eyes mainly. Significant differences between group of men and women were found. Parameters which are representing postural stability were lower at group of women and the postural stability was better at these groups of participants. It is necessary to accent that the monitored group was compound of active senior people and the results could not be globalized to all senior population.

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State of the art assessment of core stability and core strength

[1,2]E. Zemková

[1]*Department of Sports Kinanthropology, Faculty of Physical Education and Sports, Comenius University in Bratislava, Slovakia*
[2]*Sports Technology Institute, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology in Bratislava, Slovakia*
Email: zemkova@fsport.uniba.sk

Recently, core-strengthening exercises have become a part of athletic training and rehabilitation. These exercises have been promoted as a tool for enhancement of performance, rehabilitation and prevention of lumbar spine and musculoskeletal injuries. Core muscles play a role in the transfer of torques and momentum throughout the kinetic chain during a variety of job or sport specific tasks. Deficiencies in any part of the kinetic chain could lead to suboptimal performance or injury. Poor core stability incorporating muscle weakness (e.g. hip abduction), impaired balance and coordination has been associated with anterior cruciate ligament injury, patellofemoral pain, iliotibial band syndrome, low back pain, and improper landing kinematics (i.e. knee valgus). Therefore, many studies support the adoption of core training programs also for injury prevention. However, there is limited and conflicting scientific evidence on efficiency of core exercises in improving core stability and core strength. This is mainly due to a lack of firmly established training and evaluation methods. These methods should be specific to the demands imposed by sport, occupational tasks, fitness activities, and activities of daily living. This makes the training and evaluation of core function a paramount issue for practicioners and researchers in sports medicine and sports science alike. The aim of this presentation will be to introduce novel methods for assessment of core stability and core strength and their application in practice for athletes and general population.

Assessment of core stability is more challenging to measure than core muscle strength as it requires incorporating parameters of coordination and balance. The most common tests of core stability include trunk repositioning and load release tasks. The trunk repositioning task requires an individual to actively or passively move back to a neutral spine position following a predefined displacement. Load release task requires an individual to perform an isometric trunk contraction at a predefined intensity against an external load, which is subsequently released, and the displacement of the trunk is quantified. While these tests certainly hold prognostic value of injury risk, their relation to occupational exposure or sports performance in healthy individuals is unknown.

In evaluating any material manual handling such as lifting, it is essential to quantify kinetic and kinematic parameters that are able to discriminate between individuals and are sensitive to changes over time. However, there are currently no global measures taking into account arm, shoulder, trunk, and leg strength as well as the individual's lifting technique and overall fitness. Therefore, we have attempted to develop a test evaluating performance during a lifting task and a related methodology quantifying data variability under different conditions. A deadlift to high pull exercise that involves working the major muscle groups in the upper body and lower body, such as the abdomen, erector spinae, lower back and upper back, quadriceps, hamstrings and the gluteus maximus the best match such specific job demands.

The synergistic relationship between the muscles of the core and limbs has also been documented for a variety of sport specific tasks, such as overhead throwing in baseball, forehand and backhand strokes in tennis, and so forth. Usually, core strength is measured in terms how much weight/resistance a muscle can lift, how many repetitions a muscle can perform, or how long a muscle can hood a neutral stable position. However, low reliability and sensitivity of current diagnostic methods evaluating the strength of lower back muscles limits their practical application. Another drawback is that current methods does not target the major stabilizers of the spine in spite of the fact that studies showed that the most important stabilizers are task specific. To avoid these shortcomings, the FiTRO Torso Dyne system allowing users to register basic biomechanical parameters during trunk rotations was developed recently at our department. Our experience and preliminary findings regarding the rotational power in athletes of different specializations will also complement the presentation.

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INSTITUTE OF NORMAL AND PATHOLOGICAL PHYSIOLOGY
SLOVAK ACADEMY OF SCIENCES
SIENKIEWICZOVA 1
813 71 BRATISLAVA, SLOVAKIA