ACCURACY OF VISUAL FEEDBACK CONTROL OF BODY POSITION DURING TASK-ORIENTED SENSORIMOTOR EXERCISE IN VARIOUS POPULATIONS

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Abstract
The study compares the accuracy of visual feedback control of COP movement in antero-posterior and medio-lateral direction during task-oriented sensorimotor exercise in various populations. Individuals of different age and performance level (groups of healthy young adults – students of technical university, older women, and elite dancers), athletes of various specializations (competitors of snowboarding, windsurfing, cycling, rowing, canoeing, karate, and PE students), and athletes after lower limb injury (ankle, knee) volunteered to participate in the study. Subjects were provided by feedback on COM displacement on a computer screen while standing on dynamometric platform. Their task was to trace, by shifting COM, a curve flowing either in vertical or horizontal direction. The test consisted of three 30-seconds trials randomly performing in each direction. The deviation of instant COP position from the curve was recorded at 100 Hz by means of the system FiTRO Sway Check. Results showed that mean COP distance from horizontally and vertically flowing curves was significantly (p ≤ 0.01) lower in dancers (11.8 ± 2.3 mm and 10.1 ± 2.2 mm, respectively) than in students (14.8 ± 1.9 mm and 13.7 ± 2.0 mm, respectively) and older women (16.4 ± 2.6 mm and 14.5 ± 2.7 mm, respectively). On the other hand, there were no significant differences in the COP distance from both curves in competitors of snowboarding and windsurfing (20.7 ± 2.2 mm and 20.1 ± 2.2 mm, respectively), karate (20.8 ± 2.7 mm and 20.3 ± 2.7 mm, respectively), PE students (21.5 ± 3.0 mm and 20.6 ± 2.6 mm, respectively), cyclists (22.6 ± 3.0 mm and 21.3 ± 2.7 mm, respectively), and rowers (23.0 ± 2.8 mm and 22.5 ± 2.2 mm, respectively). As in previous groups, there were no significant differences in mean COP distance from horizontally and vertically flowing curve in athletes after lower limb injury while performing the task on both legs (28.7 ± 2.5 mm and 27.0 ± 2.1 mm, respectively) and on non-injured leg (42.6 ± 4.6 mm and 33.3 ± 4.2 mm, respectively). However, its values were significantly (p ≤ 0.05) higher in antero-posterior than in medio-lateral direction while standing on injured leg (50.8 ± 5.0 mm and 33.6 ± 4.5 mm, respectively). It may be concluded that the task-oriented test based on visual feedback control of body position can be applied for an evaluation of sensorimotor performance in subjects of different age and expertise, as well as in individuals after lower limb injury.

Key words: athletes, individuals after lower limb injury, older people, sensorimotor parameters, task-oriented sensorimotor exercise, visual feedback control of body position

Introduction
For many years balance has been evaluated under static conditions. However, using this method no significant differences in sway variables were found even in individuals with impaired coordination. For instance, patients with Parkinson’s disease demonstrated similar or even reduced sway of COP in comparison with healthy control subjects when tested in upright stance on stable support surface (Horak et al., 1992; Schieppati et al., 1994; Smithson et al., 1998). On the other hand, when the postural demands were increased (one-legged stance or compensation of stance perturbations) the patients showed significant deficits in their balance control. Lower sensitivity of static posturography is a consequence of multiple sensory inputs (visual, proprioceptive, and vestibular) involved in postural control. Such a system can compensate smaller impairment of the system in such a way that under normal conditions (quiet stance) no deficits in postural stability may be apparent. Under dynamic conditions (stance on unstable surface), the control mechanisms is taxed to a substantially higher extent so that individual differences can be revealed. However, though in current practice various posturography systems are available, most of them have shortcomings. First, some of the platforms, even the largest and fastest motions producing, are insufficient to destabilize subject beyond its stability limits. Though being very suitable for elderly and patients with deteriorated coordination, in highly skilled athletes does not cause serious balance impairment. Second, many of them produce only unidirectional movements, usually in antero-posterior plane.
Furthermore, in some cases the learning effect has been observed using tilted platforms since relatively high predictability of the subjects to upcoming perturbations. To avoid these drawbacks one should use more sophisticated methods closer to functional balance. Promising seems to be task-oriented sensorimotor tests performing on either stable or unstable platform equipped with PC system for feedback monitoring of COM movement (Hamar, 2008).

Advantage of the system is that there are variety of task settings like „Hit the target“ or „Trace the curve“ by horizontal shifting of COM. In the first case, subjects have to hit the target randomly appearing in one of the corners of the screen by horizontal shifting of COM in appropriate direction. The test consists of 2 sets of 20 responses while better results is taken for the evaluation. Time, distance, and velocity of COP trajectory between stimulus appearance and its hit by visually-guided COM movement on the screen are registered by means of the system FITRO Sway Check based on dynamometric platform (www.fitronic.sk). In the second, subjects are provided by feedback on COM displacement on a computer screen while standing on dynamometric platform. Their task is to trace, by shifting COM, a curve flowing either in horizontal or vertical direction. The test consists of 3 sets of 30-seconds randomly performing in antero-posterior and medio-lateral direction. The deviation of instant COP position from the curve is recorded at 100 Hz by means of the system FITRO Sway Check (www.fitronic.sk). Analysis of repeated measures showed measurement error of 8.8 % for visually-guided COM target-matching task and 7.0 % for visually-guided COM tracking task, which is within the range comparable to common motor tests.

Test-retest correlation coefficient between repeated measurements in different days was 0.81 for visually-guided COM target-matching task and 0.83 for visually-guided COM tracking task, which signify good reliability. Also the testing protocols were standardized by analysing of sensorimotor parameters under various conditions, e.g. using different velocity and positioning of the curve tracking by a visually-guided COM. In order to provide a meaningful description of an accuracy of visual feedback control of body position during COM tracking task, however, the presented system have to have also an appropriate level of sensitivity and specificity. Therefore the aim of the study was to compare the accuracy of visual feedback control of COP movement in antero-posterior and medio-lateral direction during task-oriented sensorimotor exercise in various populations.

**Methods**

**Subjects**

Various groups of subjects volunteered to participate in the study. First, individuals of different age and performance level: groups of healthy young adults – students of technical university (n = 20, age 20.9 ± 1.5 y, height 180.2 ± 7.0 cm, and weight 77.6 ± 12.3), older women (n = 20, age 54.0 ± 4.5 y, height 162.7 ± 6.1 cm, and weight 69.1 ± 15.0), and elite dancers (n = 20, age 21.0 ± 2.6 y, height 172.8 ± 11.6 cm, and weight 65.9 ± 12.4). Second, athletes of various specializations: competitors of snowboarding and windsurfing (n = 10, age 23.9 ± 3.1 y, height 174.0 ± 7.4 cm, and weight 70.5 ± 11.2), cycling (n = 5, age 24.4 ± 3.2 y, height 182.6 ± 6.5 cm, and weight 76.2 ± 11.5), rowing and canoeing (n = 13, age 23.3 ± 7.6 y, height 180.3 ± 8.5 cm, and weight 77.7 ± 14.8), karate (n = 10, age 23.2 ± 2.2 y, height 172.2 ± 7.2 cm, and weight 65.1 ± 7.8), and PE students (n = 26, age 22.7 ± 2.4 y, height 179.9 ± 7.9 cm, and weight 76.7 ± 10.2 kg). Third, athletes after lower limb injury (n = 13, age 19.6 ± 2.6 y, height 179.8 ± 8.6 cm, and weight 67.6 ± 5.1 kg). All of them were informed on the procedures and on the main purpose of the study. The procedures presented were in accordance with the ethical standards on human experimentation.

**Study setting**

![Figure 1a. Task execution: trace a curve flowing either in vertical or horizontal direction by visually-guided COM movement on the screen while standing on dynamometric platform](image-url)
Subjects were provided by feedback on COM displacement on a computer screen while standing on dynamometric platform. Their task was to trace, by shifting COM, a curve flowing either in vertical or horizontal direction (Figure 1). The test consisted of three 30-seconds trials randomly performing in each direction. The deviation of instant COP position from the curve was recorded at 100 Hz by means of the system FiTRO Sway Check developed in our department by Hamar (2007-09).

**Statistical analysis**

Ordinary statistical methods including average and standard deviation were used. A paired t-test was employed to determine the statistical significance of differences in mean COP distance from both horizontally and vertically flowing curves between examined groups, \( p < 0.05 \) was considered significant.

**Results**

Results showed that mean COP distance from both horizontally and vertically flowing curves was significantly (\( p \leq 0.01 \)) lower in dancers (11.8 ± 2.3 mm and 10.1 ± 2.2 mm, respectively) than in students (14.8 ± 1.9 mm and 13.7 ± 2.0 mm, respectively) and older women (16.4 ± 2.6 mm and 14.5 ± 2.7 mm, respectively) (Figure 2). On the other hand, there were no significant differences in the COP distance from horizontally and vertically flowing curves in competitors of snowboarding and windsurfing (20.7 ± 2.2 mm and 20.1 ± 2.2 mm, respectively).

The same situation in karate (20.8 ± 2.7 mm and 20.3 ± 2.7 mm, respectively), PE students (21.5 ± 3.0 mm and 20.6 ± 2.6 mm, respectively), cyclists (22.6 ± 3.0 mm and 21.3 ± 2.7 mm, respectively), and rowers (23.0 ± 2.8 mm and 22.5 ± 2.2 mm, respectively) (Figure 3). As in previous groups, there were no significant differences in mean COP distance from horizontally and vertically flowing curve in athletes after lower limb injury while performing the task on both legs (28.7 ± 2.5 mm and 27.0 ± 2.1 mm, respectively) and on non-injured leg (42.6 ± 4.6 mm and 33.3 ± 4.2 mm, respectively). However, its values were significantly (\( p \leq 0.05 \)) higher in antero-posterior (A-P) than in medio-lateral (M-L) direction while standing on injured leg (50.8 ± 5.0 mm and 33.6 ± 4.5 mm, respectively) (Figure 4).

Discussion and conclusion

Our previous results showed no significant differences in parameters of balance registered during quiet standing on dynamometric platform between dancers, students and older women. On the other hand, mean COP distance from both horizontally and vertically flowing curves was significantly lower in dancers than in students and older women. These findings indicate that for some athletes, untrained subjects and elderly people, the task-oriented tests based on visual feedback control of body position might represents more sensitive and therefore more appropriate testing method allowing discrimination of individuals of different age and performance level than evaluation of postural stability under static conditions. Since there are contradictory findings on relationship between proprioceptive acuity and motor skill level, we were also interested whether highly-skilled athletes of snowboarding and windsurfing would have more precise perception of COM position and its regulation in A-P and M-L direction during visually-guided COM tracking task than cyclists and rowers.

A comparison of the accuracy of visual feedback control of COP movement in both directions in athletes of different specializations showed only slightly lower values in competitors of snowboarding, windsurfing, and karate as compared to cyclists and rowers. For these athletes the regulation of COM movement based on visual feedback of its position on a computer screen likely does not represent a typical form of body control. Therefore, in order to obtain sensorimotor parameters relevant to most free-style sports, the specific test close to the one used during training or competition should be preferred. For these highly-skilled athletes, dynamic posturography seems to be more sensitive method reflecting their sport-specific adaptation (Zemková et al., 2005). However, the visually-guided COM tracking task might be an appropriate alternative for individuals after lower limb injury, namely in an early phase of rehabilitation when effusion and pain in a joint can make it exquisitely sensitive to movement when the joint is moved in a way that is perceived as possibly aggravating that injury.
Indeed, our results showed that mean COP distance from the curve was significantly higher in antero-posterior than in medio-lateral direction while performing the test on injured leg, whereas its values did not differ significantly between both directions during standing on non-injured leg and on both legs. In addition, these differences were more pronounced on ankle than knee injured leg. As regulation of body position in A-P direction is provided predominantly by ankle strategy, an increase in threshold of perception of ankle movement due to injury may be assumed. From physiology it is known that this effect may be ascribed to mainly a decreased sensitivity of receptors around the joint. It may be assumed that resulting partial reduction of afferent impulses leading to deterioration in proprioceptive feedback control of balance after injury very probably contributed to less precise perception of COM position.

And regulation its movement in antero-posterior direction, as well. Task-oriented test based on visual feedback control of body position can be applied for an evaluation of sensorimotor performance in subjects of different age and expertise (e.g., dancers), as well as in individuals after lower limb injury. However, experience showed that for some athletes (e.g., competitors in snowboarding and windsurfing) the regulation of COM movement based on visual feedback of its position on a computer screen likely does not represent a typical form of body control.

Therefore, in order to obtain sensorimotor parameters relevant to most free-style sports, the specific test close to the one used during training or competition should be preferred. A visually-guided COM tracking task does not seems to be an appropriate alternative.

**Literature**


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**Sažetak**
Istraživanje uspoređuje preciznost vizualne povratne veze COP gibanja u anterio-posteriornom i medio-lateralnom pravcu za vrijeme 'task'-usmjerenih senzomotorne vježbe kod različitih populacija. Pojedinci različitog uzrasta i razine sposobnosti (grupe zdravih mladih ljudi – studenti tehničkog univerziteta, starije žene, i elitni plesači), sportaši različitih specijalizacija (takmičari u snowboardu, windsurfingu, biciklizmu, veslanju, karateu, kao i studenti tjelesnog odgoja), te sportaši nakon povrede donjih zglobova (skočni zglog, koljeno) dobrovoljno su sudjelovali u istraživanju. Subjektima je omogućena povratna veza na COM premještanju putem računalnog monitora dok su stajali na dinamometrijskoj platformi. Zadatak im je bio da prate, pomicanjem COM-a, tok krivulje bilo u okomitom ili vodoravnom pravcu. Test se sastojao od tri 30-sekundna pokušaja slučajno izvedena u svakom pravcu. Odstupanja trenutne COP pozicije od krivulje su snimana na 100 Hz uz pomoć sistema FiTRO Sway Check. Rezultati su pokazali da je prosječna COP udaljenost od vodoravnog i okomitog toka krivulje značajno (p ≤ 0.01) niža kod plesača (11.8 ± 2.3 mm i 10.1 ± 2.2 mm, respectivno) nego kod studenata (14.8 ± 1.9 mm i 13.7 ± 2.0 mm, respectivno) i starijih žena (16.4 ± 2.6 mm i 14.5 ± 2.7 mm, respectivno). S druge strane, nije bilo značajnih razlika u COP udaljenosti obiju krivulja kod takmičara u snowboardu i windsurfingu (20.7 ± 2.2 mm i 20.1 ± 2.2 mm, respectivno), karateu (20.8 ± 2.7 mm i 20.3 ± 2.7 mm, respectivno), studenata (21.5 ± 3.0 mm i 20.6 ± 2.6 mm, respectivno), biciklista (22.6 ± 3.0 mm i 21.3 ± 2.7 mm, respectivno), i veslača (23.0 ± 2.8 mm i 22.5 ± 2.2 mm, respectivno). Kao i u prethodnim grupama, nije bilo značajnih razlika u prosječnoj COP udaljenosti od vodoravnog i okomitog toka krivulje kod sportaša koji su imali povrede donjih zglobova u izvođenju testa s obje noge (28.7 ± 2.5 mm i 27.0 ± 2.1 mm, respectivno) i na nepovrijeđenoj nozi (42.6 ± 4.6 mm i 33.3 ± 4.2 mm, respectivno). Međutim, te vrijednosti su ubile značajno (p ≤ 0.05) više u anterio-posteriornom nego u medio-lateralnom pravcu za vrijeme stajanja na povrijeđenoj nozi (50.8 ± 5.0 mm i 33.6 ± 4.5 mm, respectivno). Može se zaključiti da 'task'-usmjereni test temeljen na vizualnoj povratnoj vezi kontroluje tjelesne pozicije može biti primjenjen za evaluaciju senzomotorne sposobnosti kod subjekata različitih uzrasta i vještine, baš kao i kod pojedinaca nakon povrede zglobova donjih ekstremiteta.

**Ključne riječi:** sportaši, pojedinci nakon povrede donjih zglobova, starije osobe, senzomotorni parametri, task-usmjerno senzomotorno vježbanje, vizualna feedback kontrola tjelesne pozicije