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VISUAL FEEDBACK CONTROL OF BODY POSITION UNDER ALTERED STANCE SUPPORT CONDITIONS IN ELDERLY WOMEN

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Abstract

Aim: The study deals with visual feedback control of body position during task-oriented sensorimotor exercise performed under altered stance support conditions in elderly women.

Material and methods: Subjects were provided by feedback on COM displacement on a computer screen while standing on stable surface, foam, and spring-supported platform, respectively. 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 antero-posterior (AP) and medio-lateral (ML) direction. The deviation of instant COP position from the curve was recorded at 100 Hz by means of the system FiTRO Sway Check. The same system was used to register mean distance from the middle of COP while standing on either stable or foam surface with eyes open (EO) and eyes closed (EC), respectively.

Results: Results showed that a deprivation of visual control and reduced stance support led to significantly ($P \leq 0.01$) higher mean distance from the middle of COP as compared to standing on stable surface with EC. Its values were also significantly ($P \leq 0.05$) higher during standing on foam with EO than on stable surface with EO. On the other hand, there were no significant differences in mean COP distance from the curve while performing visually-guided COM tracking task on stable and on foam surface. In addition, mean COP distance from horizontally and vertically flowing curve did not differ significantly while standing on stable (23.6 ± 4.4 mm and 20.8 ± 4.0 mm, respectively) and foam surface (23.5 ± 3.8 mm and 21.2 ± 3.7 mm, respectively). However, its values were significantly ($P \leq 0.01$) higher in antero-posterior than in medio-lateral direction (33.2 ± 4.7 mm and 22.2 ± 3.9 mm, respectively) during stance on spring-supported platform. A combination of spring-supported platform and foam showed the same tendency but its values were only slightly higher (35.1 ± 4.7 mm and 23.9 ± 4.6 mm, respectively) than during standing on spring-supported platform. These differences were caused mainly by increasing the COP distance from horizontally flowing curve. Its values were even significantly ($P \leq 0.01$) higher as compared to those registered during stance on stable and foam surface.

Conclusions: It may be concluded that a) visual feedback control of body position compensates for reduced proprioceptive information during standing on foam surface, and that b) dynamic conditions better differentiate sensorimotor parameters in antero-posterior and medio-lateral direction during visually-guided COM tracking task.

Key words: *postural sway, sensorimotor parameters, task-oriented sensorimotor exercise, testing conditions, 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 healthly control subjects when tested in upright stance on stable support surface [1, 2]. 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 these are very suitable for elderly and patients with deteriorated coordination, in highly skilled athletes do 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 because of 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 [3]. 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 being 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 three 30-seconds trials 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 [4]. 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.

Experience showed [5] that these task-oriented tests 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. However, different results can be assumed depending on experimental conditions in which sensorimotor parameters are measured.

Therefore the aim of the study was to evaluate the effects of altered stance support conditions on visual feedback control of body position during task-oriented sensorimotor exercise in elderly women.

Methods

Subjects

A group of 10 older women (age 52.2 ± 7.6 y, height 164.3 ± 5.1 cm, and weight 74.3 ± 19.3 kg) volunteered to participate in the study. 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

Subjects were provided by feedback on COM displacement on a computer screen while standing on different support surfaces (stable platform, foam, and spring-supported platform, respectively). Their task was to trace, by shifting COM, a curve flowing either in vertical or horizontal direction (Fig. 1). The test consisted of three 30-seconds trials randomly performing in antero-posterior (AP) and medio-lateral (ML) 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 [6].

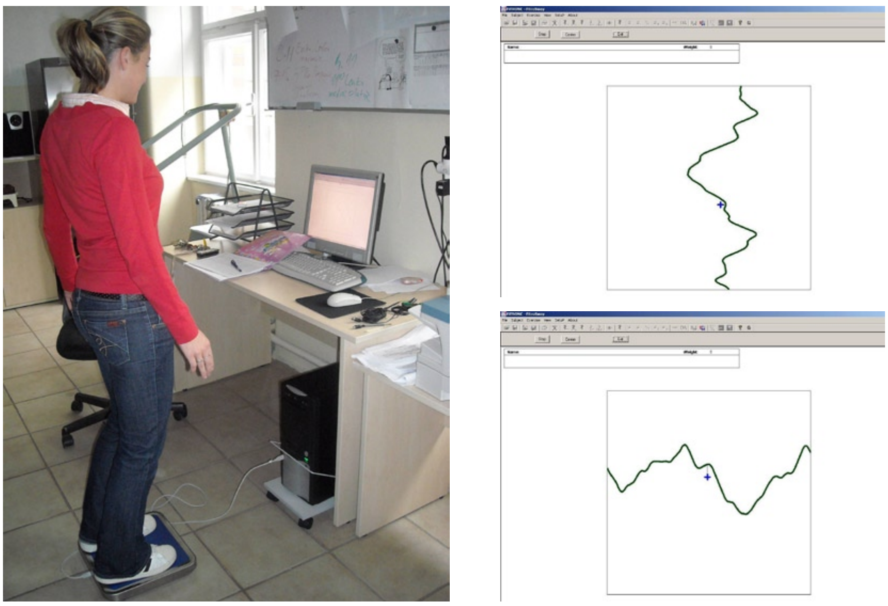


Fig. 1. *Task execution: trace a curve flowing either in vertical or horizontal direction by visually-guided COM movement on the screen while standing on dynamometric platform*

Postural stability was evaluated under both static and dynamic conditions (foam) with eyes open and eyes closed, respectively. Mean distance from the middle of COP was registered at 100 Hz by means of the posturography system FiTRO Sway Check based on dynamometric platform. Subjects were instructed to minimize postural sway by standing as still as possible.

Statistical analysis

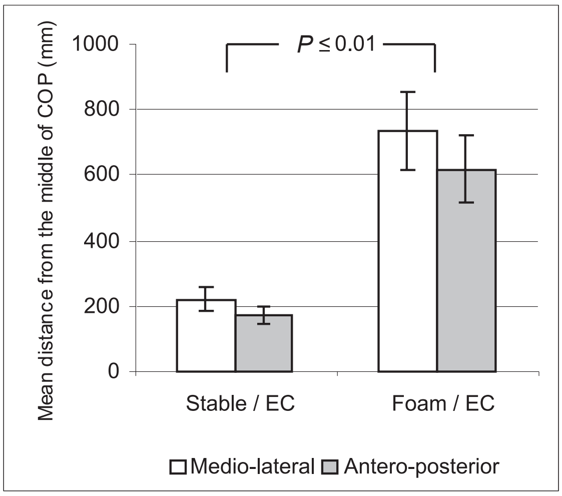
Ordinary statistical methods including average and standard deviation were used. A paired t-test was employed to determine the statistical significance of differences in sensorimotor parameters between testing conditions applied, $P \leq 0.05$ was considered significant.

Results

Results showed that a deprivation of visual control and reduced stance support led to significantly ($P \leq 0.01$) higher mean distance from the middle of COP as compared to standing on stable surface with EC (Fig. 2a). Its values were also significantly ($P \leq 0.05$) higher during standing on foam with EO than on stable surface with EO (Fig. 2b).

On the other hand, there were no significant differences in mean COP distance from the curve while performing visually-guided COM tracking task on stable and on foam surface (Fig. 3). In addition, postural control was more compromised in antero-posterior than in medio-lateral direction during task-oriented sensorimotor exercise whereas opposite was true for quiet standing.

As has been shown, there were no significant differences in mean COP distance from horizontally and vertically flowing curve while standing on stable (23.6 ± 4.4 mm and 20.8 ± 4.0 mm, respectively) and foam surface (23.5 ± 3.8 mm and 21.2 ± 3.7 mm, respectively). However, its values during stance on spring-supported platform were significantly ($P \leq 0.01$) higher in antero-posterior than in medio-lateral direction (33.2 ± 4.7 mm and 22.2 ± 3.9 mm, respectively). A combination of



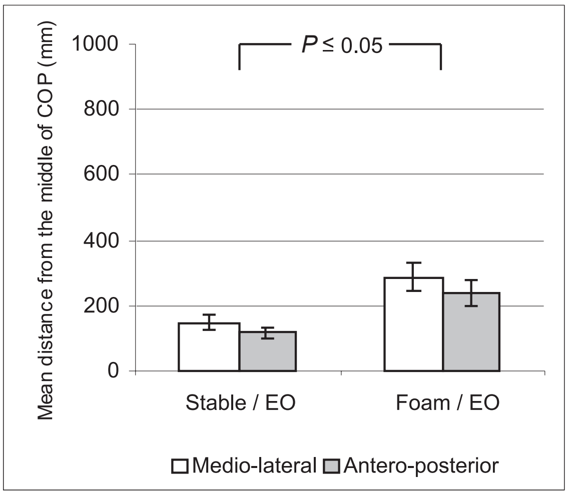


Fig. 2. *Mean distance from the middle of COP in M-L and A-P direction during standing on either stable or foam surface with (a) eyes closed and (b) eyes open, respectively*

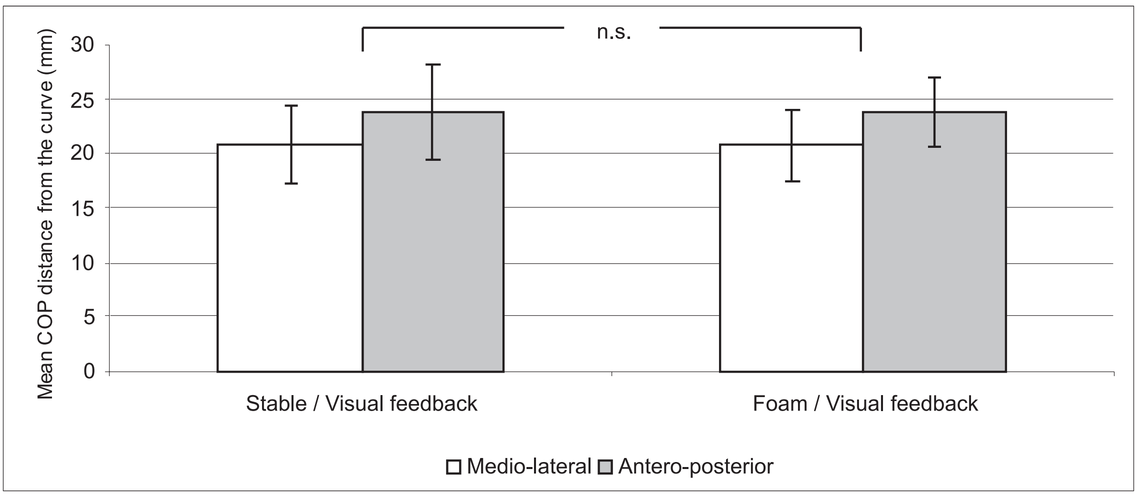


Fig. 3. *Mean COP distance from the curve in M-L and A-P direction registered during visually-guided COM tracking task while standing on either stable or foam surface*

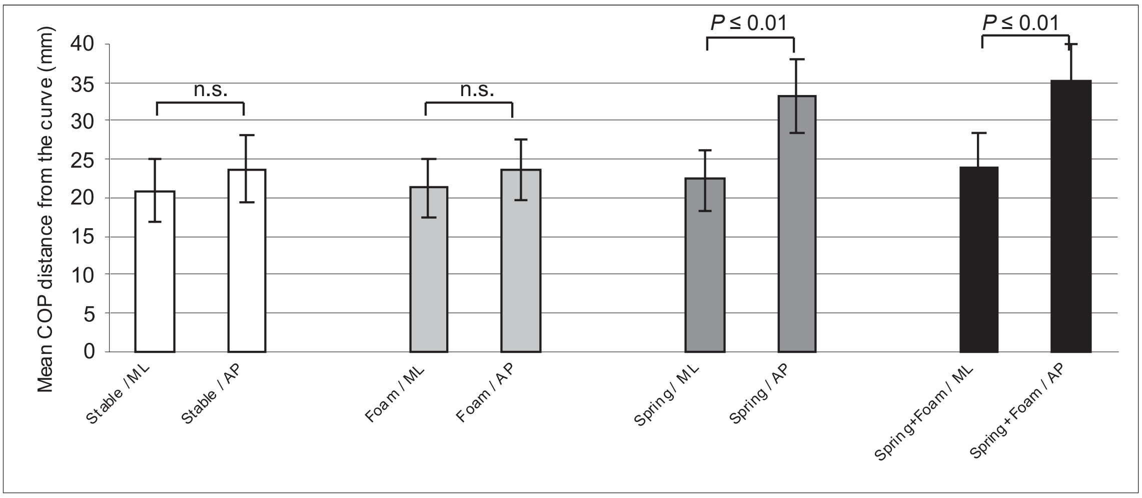


Fig. 4. *Mean COP distance from the curve in M-L and A-P direction registered during visually-guided COM tracking task under various stance conditions*

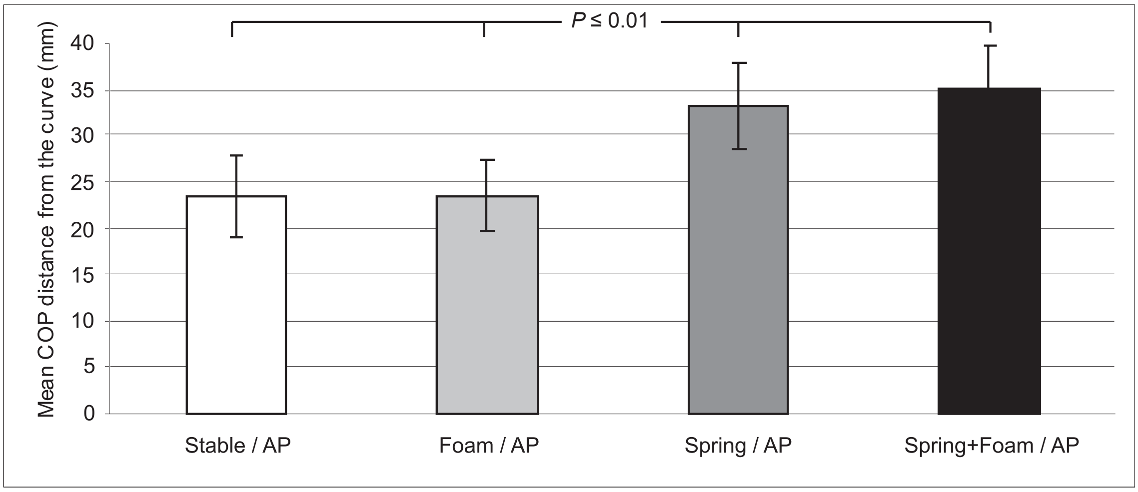


Fig. 5. *Mean COP distance from horizontally flowing curve registered during visually-guided COM tracking task under various stance conditions*

spring-supported platform and foam showed the same tendency but its values were only slightly higher (35.1 ± 4.7 mm and 23.9 ± 4.6 mm, respectively) than during standing on spring-supported platform (Fig. 4). These differences were caused mainly by increasing the COP distance from horizontally flowing curve. Its values were even significantly ($P \leq 0.01$) higher as compared to those registered during stance on stable and foam surface (Fig. 5).

Discussion

It is well known that when the reliability of proprioceptive information is reduced, either by standing on sway-referenced surface [7] or on compliant foam surface [8], there is an increased attention demand associated with maintenance of balance. Particularly, vision is of greater relevance when the demands on postural task are increased [9, 10]. According to Taube et al. [11] there is a significant interaction between the visual and the support surface conditions indicating that the H-reflex is more strongly affected by changes in visual feedback during standing on unstable surface. However, there is lack of information on the role of vision and stance support conditions in task-oriented sensorimotor exercise.

Therefore we compared postural sway in antero-posterior and medio-lateral direction while standing either on stable or foam surface a) without visual control, b) with eyes open, and c) during visually-guided COM tracking task. It has been found that a deprivation of visual control and reduced stance support led to significantly higher mean distance from the middle of COP as compared to standing on stable surface with EC. Its values were also significantly higher during standing on foam with EO than on stable surface with EO. On the other hand, there were no significant differences in mean COP distance from the curve while performing visually-guided COM tracking task on stable and on foam surface. In addition, postural control was more compromised in antero-posterior than in medio-lateral direction during task-oriented sensorimotor exercise whereas opposite was true for quiet standing. It may be assumed that visual feedback control of body position compensates for reduced proprioceptive information during standing on foam surface.

As has been shown [12] there are no significant differences in mean COP distance from the curve in antero-posterior and medio-lateral direction while performing visually-guided COM tracking task on stable surface. We were interested whether dynamic conditions would better differentiate sensorimotor parameters in A-P and M-L direction during such a task-oriented sensorimotor exercise. Therefore, we evaluated an accuracy of visual feedback control of COP movement in antero-posterior and medio-lateral direction during visually-guided COM tracking task performed under different stance support conditions.

Results showed no significant difference in mean COP distance from horizontally and vertically flowing curve while standing on stable and foam surface. However, its values were significantly higher in antero-posterior than in medio-lateral direction during stance on spring-supported platform. A combination of spring-supported platform and foam showed the same tendency but its values were only slightly higher than during standing on spring-supported platform. These differences were caused mainly by increasing the COP distance from horizontally flowing curve. Its values were even significantly higher as compared to those registered during stance on stable and foam surface. It means that dynamic conditions better differentiate sensorimotor parameters in antero-posterior and medio-lateral direction during visually-guided COM tracking task.

These findings may be of importance for the conception and evaluation of visual feedback therapy interventions. For instance, Van Peppen et al. [13] argued that visual feedback training while bilateral standing on two force plates was not superior to conventional therapy. To provide visual feedback in more demanding and functional balance tasks (e.g., the stance on spring-supported platform) may represent more effective alternative than performing task-oriented sensorimotor exercise on stable surface. However, further studies are needed to prove this assumption.

Conclusion

Investigation of the effects of altered stance support conditions on visual feedback control of body position during task-oriented sensorimotor exercise showed that a) visual feedback control of body position compensates for reduced proprioceptive information during standing on foam surface, and that b) dynamic conditions better differentiate sensorimotor parameters in antero-posterior and medio-lateral direction during visually-guided COM tracking task.

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A – Study Design	C – Statistical Analysis	E – Manuscript Preparation	G – Funds Collection