HUMAN MOVEMENT
2010, vol. 11 (2), 119–123

THE EFFECT OF TASK-ORIENTED SENSORIMOTOR EXERCISE ON VISUAL FEEDBACK CONTROL OF BODY POSITION AND BODY BALANCE

doi:10.2478/v10038-010-0013-3

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ABSTRACT
Purpose. The study evaluates the effect of task-oriented sensorimotor exercise on visual feedback control of body position and parameters of static and dynamic balance. **Basic procedures.** A group of 20 PE students (aged 21.5 ± 1.6 years, height 178.2 ± 10.6 cm, and weight 74.5 ± 11.8 kg) performed task-oriented sensorimotor exercise (20 sets of 60 stimuli with 2 min rest in-between). They had to hit the target randomly appearing in one of the corners of the screen by horizontal shifting of COM in appropriate direction. Response time, distance, and velocity of COP trajectory were registered during standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement. Postural stability was evaluated under both static and dynamic conditions (wobble board). The COP velocity was registered at 100 Hz by means of the posturography system FiTRO Sway Check based on dynamometric platform. **Main findings.** Mean response time significantly ($p \leq 0.01$) decreased from 3100.5 ± 1019.8 ms to 1745.8 ± 584.5 ms. Substantial share of the improvements took place during initial 6 trials. At the same time also mean distance of COP movement significantly ($p \leq 0.05$) decreased from 0.767 ± 0.340 m to 0.492 ± 0.190 m within initial 12 trials and then slightly increased up to 0.591 ± 0.247 m. On the other hand, mean COP velocity significantly ($p \leq 0.05$) increased from 0.285 ± 0.142 m/s to 0.395 ± 0.182 m/s. However, there were no changes in the COP velocity registered in static (from 12.4 ± 1.8 mm/s to 11.9 ± 1.5 mm/s) and dynamic conditions (from 108.0 ± 22.3 mm/s to 101.3 ± 18.1 mm/s). **Conclusions.** Task-oriented sensorimotor exercise acutely enhances visual feedback control of body position but not static and dynamic balance.

Key words: acute effect, static and dynamic balance, task-oriented sensorimotor exercise, visual feedback control of body position

Introduction

Balance is the ability to maintain a given posture with minimal movement sway in static or dynamic conditions. Also stance symmetry in terms of weight distribution between the feet in a standing position plays a role in maintaining balance. However, it has also to be taken into account that balance in most situations is associated with other tasks (e.g., picking up an object or kicking a ball). From this point of view it is important to focus the exercise programs on improvement of postural control to be flexible and adaptable to perturbations.

Recently, various forms of balance exercises have become a part of both athletic training and rehabilitation. However, improvement after such training seems to be task-specific. For instance, no crossover effects of functionally directed instability resistance training on parameters of static balance in athletes after ACL reconstruction have been found [1]. A similar finding, an improvement of dynamic but not static balance, has been documented [2] after combined agility-balance training in elite basketball players. Also, in untrained subjects balance exercises performed simultaneously with reaction tasks have been found [3] as an effective means of improving balance in dynamic conditions, namely when responding to visual stimuli. However, the training program applied has proved to be insufficient to improve visual feedback control of body balance.

For this purpose as a suitable alternative seems to be platform feedback exercises providing visual or auditory biofeedback to subjects regarding the locus of their centre of pressure (COP). Typical force platform biofeedback systems consist of at least two force plates to allow the weight on each foot to be determined, a computer and a monitor to allow visualization of the COP, and software that provides training protocols and data analysis capabilities. Some units allow auditory feedback in addition to the visual feedback in response to errors in performance. However, platform feedback exercises have been found [4] to improve stance symmetry but not sway in standing and clinical balance outcomes (Berg Balance Scale and Timed Up and Go). Even no changes in symmetry of weight distribution, postural sway in bilateral standing, gait and gait-related activities after visual feedback training were reported by Van Peppen et al. [5]. The authors argued that such

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exercise performed on stable support surfaces is not superior to a conventional therapy.

Thus, even more sophisticated methods, namely those enabling both practice and assessment of visual feedback control of body position are needed. Promising seem to be those closer to functional activities like task-oriented sensorimotor exercises performed on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement [6]. Such training (3-week program consisting of 3 sets of 200 stimuli with 5 min rest in-between, 3 times a week) has been found [7] to contribute to more precise perception of COM position and regulation of its movement leading to faster responses to visual stimuli, as well as more rapid postural sway adjustments in altered surface conditions.

From practical point of view, the question remains whether similar effect may be achieved also during short-term practice. Therefore, the aim of the study was to evaluate the effect of task-oriented sensorimotor exercise on visual feedback control of body position and parameters of static and dynamic balance.

Material and methods

Subjects

A group of 20 PE students (aged 21.5 ± 1.6 years, height 178.2 ± 10.6 cm, and weight 74.5 ± 11.8 kg) volunteered to participate in the study. All of them were informed about the procedures and the main purpose of the study. The procedures presented were in accordance with the ethical standards on human experimentation.

Study setting

Subjects performed task-oriented sensorimotor exercise (20 sets of 60 stimuli with 2 min rest in-between). They were provided with feedback on COM displacement on a computer screen while standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement (Fig. 1). Their task was to hit the target randomly appearing in one of the corners of the screen by horizontal shifting of COM in the right direction. Response time, distance, and velocity of COP trajectory between stimulus appearance and its hit by visually-guided COM movement on the screen were registered by means of the above mentioned system developed at our Department by Hamar et al. [8].

Prior to and after the last set of task-oriented sensorimotor exercises also postural stability was evaluated under both static and dynamic conditions (wobble board). Velocity of the centre of pressure (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 em-

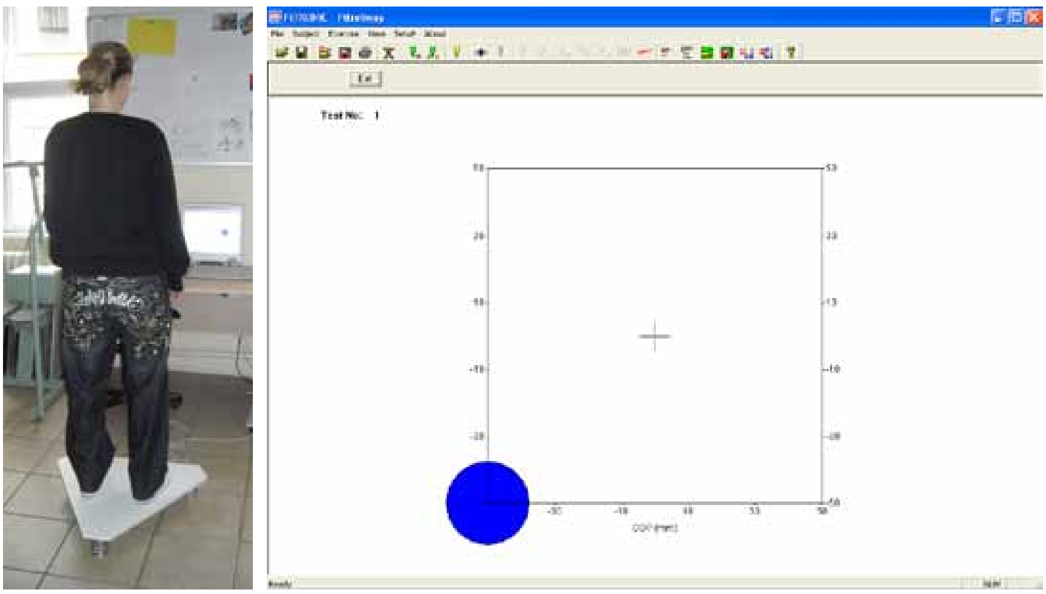


Figure 1. Task execution: hit the target by shifting COM in one of the four directions according to position of stimulus on the screen while standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement (www.fitronic.sk)

ployed to determine the statistical significance of differences between pre- and post-exercise values of examined abilities, $p < 0.05$ was considered significant.

Results

It has been found that the mean response time (Fig. 2) significantly ($p \leq 0.01$) decreased from 3100.5 ± 1019.8 ms to 1745.8 ± 584.5 ms. Substantial share of the improvements took place during initial 6 trials.

At the same time also the mean distance of COP movement (Fig. 3) significantly ($p \leq 0.05$) decreased from 0.767 ± 0.340 m to 0.492 ± 0.190 m within initial 12 trials and then slightly increased up to 0.591 ± 0.247 m.

On the other hand, the mean COP velocity (Fig. 4) significantly ($p \leq 0.05$) increased from 0.285 ± 0.142 m/s to 0.395 ± 0.182 m/s.

However, there were no changes in the COP velocity (Fig. 5 a, b) registered in static (from 12.4 ± 1.8 mm/s to 11.9 ± 1.5 mm/s) and dynamic conditions (from 108.0 ± 22.3 mm/s to 101.3 ± 18.1 mm/s).

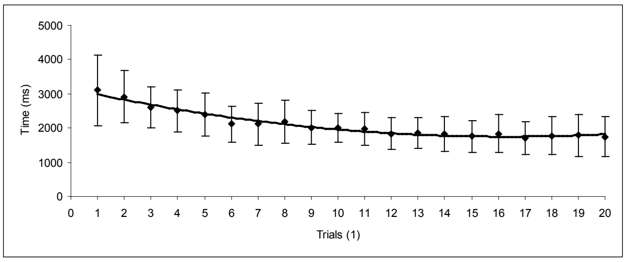


Figure 2. Response time measured during task-oriented sensorimotor exercise

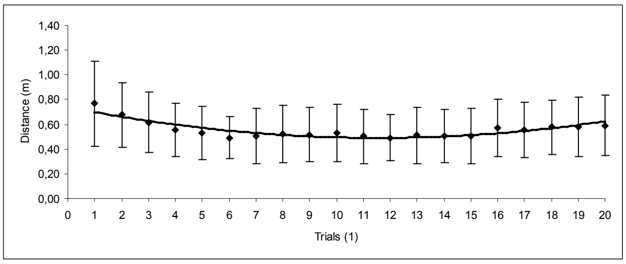


Figure 3. Distance of sway trajectory measured during task-oriented sensorimotor exercise

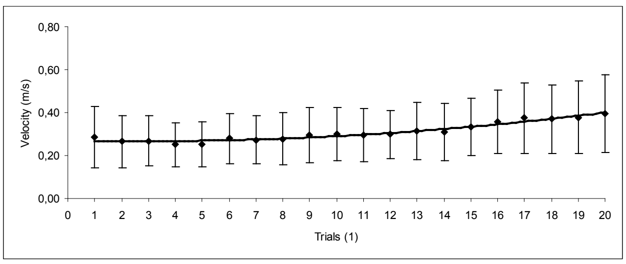
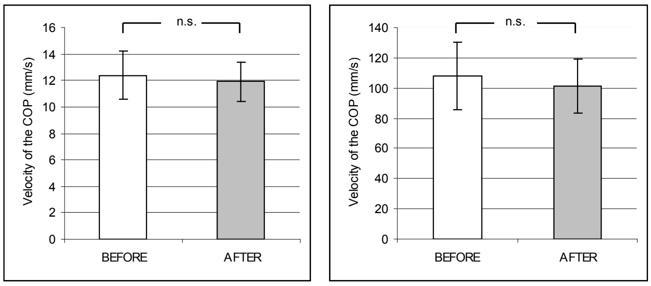


Figure 4. Sway velocity measured during task-oriented sensorimotor exercise



a) b)

Figure 5. The COP velocity registered in (a) static and (b) dynamic conditions prior to and after 20 sets of task-oriented sensorimotor exercises

Discussion

Task-oriented sensorimotor exercise decreased the time response from the 1st to the 20th trial by 1355 ms (44%). Also the distance of COP movement decreased from the 1st to the 12th trial by 0.275 m (36%) and then slightly increased to 0.099 m within the 20th trial (17%). On the other hand, the COP velocity increased from the 1st to the 20th trial by 0.11 m/s (28%). Such a more precise perception of COM position and regulation of its movement leading also to faster responses to visual stimuli may demonstrate the enhancement of visual feedback control of body position.

From physiology it is known that such an effect may be the consequence of enhancement in spinal excitability [9, 10]. Taube et al. [11] supposed that enhanced visual feedback interacts with the spinal reflex system in terms of facilitated Ia-afferent transmission. From a functional point of view, higher Ia-afferent transmission may be advantageous to activate easily the motoneuron pool [12 – 14]. This mechanism may contribute to the improvement of fine motor control in response to visual stimuli and reduction in postural sway.

More specifically, Taube et al. [11] found that the H-reflex modulation was directly opposed to the changes in COP displacement. It means, the less the subjects swayed, the greater their reflexes were. There are different supraspinal sites like the motor cortex [15], the cerebellum [16] and the basal ganglia [17] which potentially influence the spinal reflex excitability. They are all dependent on feedback from visual, vestibular, cutaneous and proprioceptive sources.

Though it is not known whether any positive adjustments would be mediated through central processing, the task-oriented sensorimotor exercise applied certainly tax a proprioceptive control of posture. Muscle proprioceptive inputs continuously inform the central nervous system about the position of each part of the body in relation to the others [18, 19]. Eklund [20] established that oriented whole-body tilts could be induced in standing human subjects by applying vibratory stimulation to the ankle postural muscles, i.e., stimulation of the tibialis anterior muscles results in a forward tilt and stimulation of the triceps surae muscles causes a backward tilt. Similar finding was observed in other muscles, e.g., paravertebral [21, 22], cervical [23 – 25], and extraocular [26]. In all these cases, the induced postural responses were oriented in specific directions, depending on the vibrated muscles. Therefore, Roll and Roll [25] suggested that muscle-spindle inputs might form a continuous "proprioceptive chain" from the feet to the eyes, since applying tendon vibration at any level in the chain apparently alters the internal representation of the body posture.

Like the somatosensory [27] and vestibular system [28, 29], also the visual system may be capable of influencing the spinal reflex excitability, as proposed by Hoffman and Koceja [30]. In contrast to this study, Taube et al. [11] observed a significant interaction between the visual and the support surface conditions indicating that the H-reflex was more strongly affected by changes in visual feedback on the unstable surface. This is in line with the observation that vision is of greater relevance when the demands of the postural task are increased [31, 32]. In order to provide visual feedback in more demanding and functional balance tasks, a standing on unstable spring-supported platform may be a more appropriate alternative than systems consisting of two stable force plates.

However, in healthy subjects reduced COP amplitudes were shown when the COP was displayed on a computer screen but at the same time sway frequency increased [33, 34]. Such a change in the postural control strategy was argued to reflect a "tighter" but not essentially better control of body sway. Interestingly, "tighter" postural control during quiet stance has also been reported for cognitive dual tasks [35] and for tasks involving postural threats [36, 37]. Thus, the secondary task of hitting the target by visually-guided COM movement on the screen may not (only) alter the visual feedback control of body position but also lead to changes in the subjects' level of attention or arousal, which in turn, may influence the postural control strategy. This assumption is in accordance with our previous findings [38] that sway velocity registered under dynamic conditions declines when concurrently performing a secondary reaction task. This effect was found to be more evident for multi-choice than simple responses.

These findings may be of some importance for the conception of visual feedback therapy interventions. This includes selection of the biofeedback system based on either force or unstable spring-supported platform, type of task-oriented exercise (visually-guided COM tracking or target-matching task), as well as investigation of an efficient exercise mode for such a training including an optimal practice-rest ratios, and so forth. Further studies are also needed to evaluate the application of task-oriented sensorimotor exercise in rehabilitation setting for individuals after lower limb injury and in prevention of falls in elderly population.

Conclusions

Task-oriented sensorimotor exercise acutely decreases the response time and distance of COP movement, and increases the COP velocity registered during standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement. It means that with repeated trials subjects respond to visual stimuli faster and more precisely by horizontal shifting of COM in one of the four directions according to position of stimulus on the screen. However, such an acute enhancement of visual feedback control of body position during practice is not beneficial for improvement of static and dynamic balance. As shown in our previous study long-term application of task-oriented sensorimotor exercise is needed in order to achieve adaptive changes in postural control system.

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Paper received by the Editors: August 6, 2009.
Paper accepted for publication: February 24, 2010.

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