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VISUAL REACTION TIME AND SWAY VELOCITY WHILE BALANCING ON A WOBBLE BOARD

VIZUALNI REAKCIJSKI ČAS IN HITROST NIHANJA MED LOVLJENJEM RAVNOTEŽJA NA RAVNOTEŽNI DESKI

Abstract

The study investigates the reaction time and sway velocity while responding to visual stimuli while balancing on wobble board. A group of 22 PE students responded in random order to either one or two visual stimuli while standing on unstable support surface for a period of three minutes. During the task, both sway velocity and reaction time were measured. Centre of pressure (COP) velocity was registered at 100 Hz by means of the posturography system FiTRO Sway Check based on a dynamometric platform. Simple and multi-choice reaction times were measured using FiTRO Reaction Check. The results showed no changes in simple reaction time while balancing on the wobble board (394.3 ± 27.6 ms and 432.7 ± 31.1 ms, respectively). However, multi-choice reaction time significantly ($p \leq 0.05$) increased from an initial 5-sec to the final 5-sec period of the test (from 644.1 ± 35.2 ms to 714.5 ± 43.6 ms). In contrast, COP velocity gradually decreased during the simple reaction task (from 159.2 ± 30.2 mm/s to 135.0 ± 25.0 mm/s). When responding on two stimuli, there was a significant ($p \leq 0.05$) decrease in COP velocity for an initial 2:15 min (from 144.5 ± 28.8 mm/s to 102.4 ± 18.1 mm/s), which was followed by its slight increase toward the end of the test (126.6 ± 22.8 mm/s). Interestingly, the multi-choice task induced greater balance improvement in comparison to simple reactions. It may be concluded that reaction time increases while balancing on wobble board, whereas sway velocity declines when concurrently performing reaction task.

Keywords: dynamic balance, simple and multi-choice reaction time

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Povzetek

Študija proučuje reakcijski čas in hitrost nihanja glede na vizualne dražljaje med lovljenjem ravnotežja na ravnotežni deski. Skupina 22 študentov športne vzgoje je naključno reagirala na eno ali dve vrsti vizualnih dražljajev med triminutnim stanjem na ravnotežni deski. Med izvajanjem naloge smo merili hitrost nihanja in reakcijski čas. Hitrost središča pritiska smo merili pri 100 Hz pomočjo sistema proučevanja drže FiTRO Sway Check, ki temelji na dinamometrični platformi. Enostavne in kompleksne, več-izbirne reakcijske čase smo merili s sitemom FiTRO Reaction Check. Analiza ni pokazala nobenih razlik v enostavnih reakcijskih časih med lovljenjem ravnotežja (394,3 ± 27,6 ms oziroma 432,7±31,1 ms), v kompleksnih reakcijskih časih pa se je reakcijski čas v zadnjih 5 sekundah testa značilno povečal ($p \leq 0,05$) v primerjavi s prvimi 5 sekundami testa (od 644,1 ± 35,2 ms na 714,5 ± 43,6 ms). Nasprotno pa se je je hitrost središča pritiska med nalogo enostavne reakcije postopno zmanjševala. V odzivu na dva dražljaja se je hitrost središča pritiska značilno zmanjšala ($p \leq 0.05$) v prvih 2:15 min (od 144,5 ± 28,8 mm/s na 102,4 ± 18,1 mm/s), rahlo pa se je povečala proti koncu testa (126,6 ± 22,8 mm/s). Zanimivo je, da je kompleksnejša naloga povzročila večje izboljšanje ravnotežja kot enostavnejša. Lahko bi sklepali, da se reakcijski čas med lovljenjem ravnotežja poveča, da pa se hitrost nihanja zmanjšuje, če med lovljenjem ravnotežja izvajamo test reakcijskega časa.

Ključne besede: dinamično ravnotežje, enostavni in več-izbirni reakcijski časi

Introduction

The traditional view regarding postural activities as reflex-like responses elicited automatically by a sensory stimulus has been revised. Recent studies using a dual-task paradigm have proved that postural control requires attentional resources (for a review see Woollacott and Shumway-Cook, 2002). Postural control is now considered to be a perceptual-motor process that includes sensation of position and motion from the visual, somatosensory, and vestibular systems; processing of that sensory information to determine body orientation and movement; and selection of motor responses that bring the body into equilibrium.

In spite of this view, in current practice static conditions are usually provided for the assessment of postural stability. However, asking subjects to perform a balance-alone task is somewhat unnatural. In such a task, subjects are encouraged to remain as stable as possible, thus focusing attention on their body sway. Introducing a secondary task seems to be more similar to natural situations. It would force the subjects to focus more attention onto this secondary task and to fully delegate postural control to sensory-motor processes. In fact, deliberately controlling posture seems to be less efficient than controlling posture more automatically.

It may be assumed that performing a concurrent task while standing upright would facilitate postural control at a sensory-motor level. However, studies investigating the effect of cognitive resources on postural control have provided contradictory results. During the execution of the dual task, it has been shown that postural sway decreases (Maki, McIlroy, 1996; Andersson et al., 1998; Rankin et al., 2000; Shumway-Cook, Woollacott, 2000), remains unchanged (Stelmach et al., 1990; Yardley et al., 1999), or increases (Kerr et al., 1985). For instance, Vuillerme et al. (2000) reported that COP displacements measured using a force plate significantly decrease while concurrently performing reaction tasks (measurement on six male volunteers). However, our experience showed (e.g., Zemková, Hamar, 2008) no changes in COP variables even after balance-specific training in young healthy individuals; therefore, one can hardly expect improvement of static balance by increasing attention in form of processing a reaction task. In this case, dynamic conditions seem to be more appropriate alternative.

It is known that as a postural task becomes more difficult, increase in attention is required (Bardy, Laurent, 1991; Lajoie et al., 1993; Teasdale et al., 1993; Lajoie et al., 1996; Yardley et al., 2001). Specifically, when the proprioceptive information was reduced, either by standing on a sway-referenced floor (Redfern et al., 2001) or on a compliant foam surface (Teasdale et al., 1993), an increased attentional demand associated with maintaining a stable position was observed.

However, questions remain how simple and multi-choice reaction tasks that require different level of attention would influence dynamic balance and, in turn, how reaction time would change during balancing on the wobble board.

Therefore, the aim of the study was to investigate the reaction time and sway velocity while responding on visual stimuli concurrently with balancing on the wobble board.

Methods

Subjects

A group of 22 PE students (age 22.4 ± 2.6 y, height 180.6 ± 5.7 cm, and weight 77.8 ± 5.2 kg) volunteered to participate in the study. All of them were informed of the procedures and of the main purpose of the study.

Test protocol and diagnostic equipments

Subjects performed reaction tasks concurrently with balancing on the wobble board for a period of three minutes (Fig. 1). They had to respond to visual stimuli of different colours randomly appearing in the middle of the screen by pressing a button placed close to their fingers. Variation of attentional demand of the secondary RT task was provided in random order by responses on one and two stimuli. The FiTRO Reaction check diagnostic system was used to generate stimuli and measure corresponding reaction time.

Simultaneously, the COP velocity was registered at 100 Hz by means of the FiTRO Sway Check posturography system, based on dynamometric platform. Subjects were instructed to minimize postural sway by standing as still as possible. Average values of 5-second intervals were used for the analysis.

Figure 1: Task execution – responding on either one or two visual stimuli provided concurrently with keeping the balance platform horizontal, or as close to horizontal 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 between values in different tasks, $p < 0.05$ was considered significant.

Results

No changes have been found in simple reaction time while balancing on wobble board (Fig. 2) (394.3 ± 27.6 ms and 432.7 ± 31.1 ms, respectively). However, multi-choice reaction time significantly ($p \leq 0.05$) increased from an initial 5-sec to the final 5-sec period of the test (from 644.1 ± 35.2 ms to 714.5 ± 43.6 ms).

In contrast, COP velocity (Fig. 3) gradually decreased during the simple reaction task (from 159.2 ± 30.2 mm/s to 135.0 ± 25.0 mm/s). However, a significant ($p \leq 0.05$) decrease was found when responding on two visual stimuli. This effect was observed only for an initial 2:15 min (from 144.5 ± 28.8 mm/s to 102.4 ± 18.1 mm/s), which was followed by its slight increase toward the end of the test (126.6 ± 22.8 mm/s). Interestingly, the multi-choice task induced greater balance improvement as compared to simple reactions.

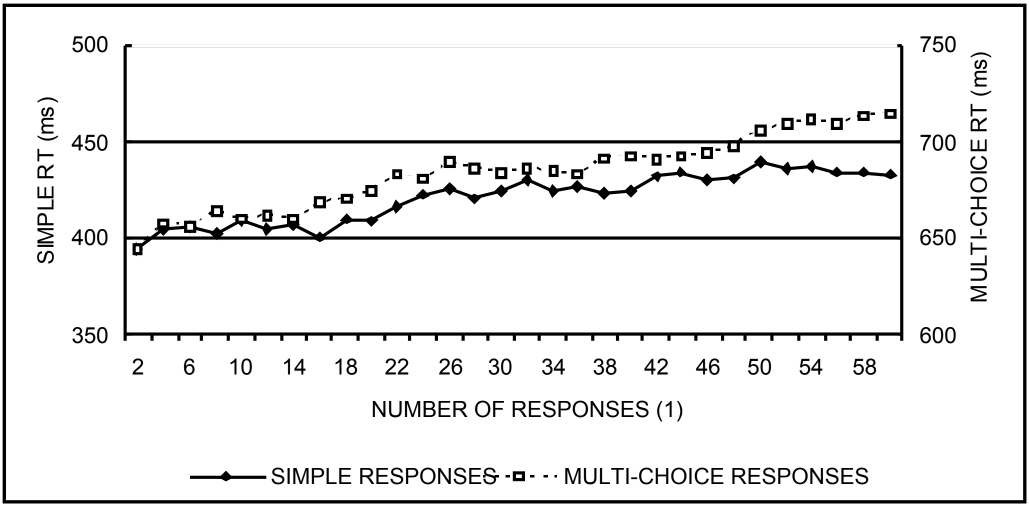

Figure 2: Simple and multi-choice reaction time measured during standing on the wobble board

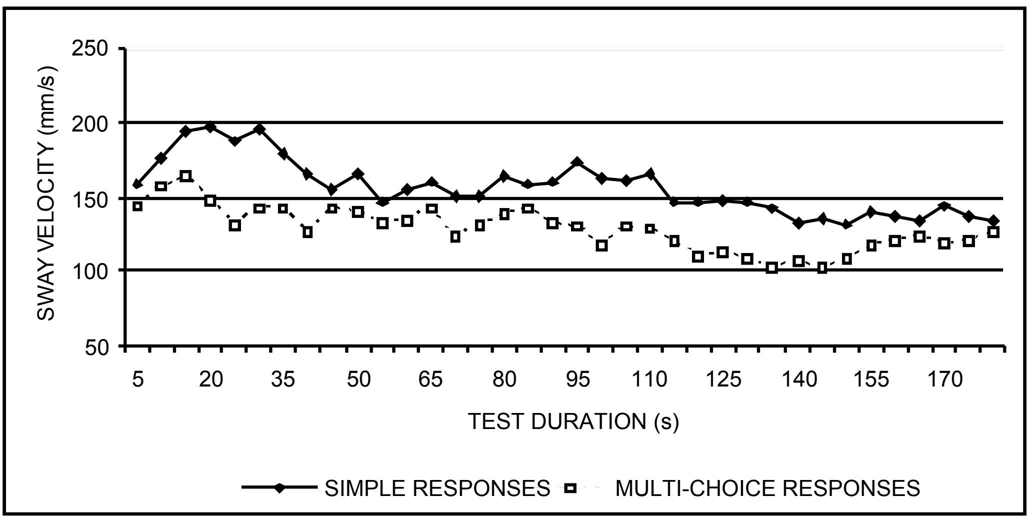

Figure 3: Sway velocity during concurrent RT tasks

Discussion

The attentional demand for maintaining an upright posture on an unstable support surface is higher under multi-choice than simple reaction conditions, as indexed by higher RT. This result is partly in agreement with the findings of Redfern and Jennings (1998), who documented increase both simple RT and more difficult inhibitory RT as the difficulty of the postural task increased. Similarly, increasing the postural constraint has been found (Kerr et al., 1985; Lajoie et al., 1993; Teasdale et al., 1993; Andersson et al., 1998) to negatively affect the performance of a concurrent secondary cognitive task. This effect is supposed to reflect the allocation of attentional resources to the control of stability during an upright stance.

In contrast, there was an improvement of dynamic balance while responding to visual stimuli. This effect was more evident for multi-choice than simple reaction tasks. Such a positive effect of a secondary task on postural stability may be ascribed to increased level of subjects' attention when they were forced to cope with the requirements of reaction tasks. Similarly, McChesney et al. (1996) reported that providing non-specific information on a forthcoming balance perturbation created an alert state that reduced the onset latency of postural muscles in response to the perturbation.

In this cohort, a negative correlation between the reaction time and anticipatory postural adjustments (APAs) onset was found (Slijper et al., 2002). The relative APA timing showed a significant relation to the actual value of reaction time, such that a 1 ms increase in reaction time corresponded to an increase in the delay between APA and focal-action onsets of between 0.1 and 0.6 ms. APAs were on average delayed by an additional 5 ms under simple reaction time conditions as compared to choice reaction time conditions. This finding may in part explain that sway velocity was lower when performing simple rather than multi-choice responses on an unstable platform.

From physiological point of view, the upright position is maintained by muscles acting against the force of gravity, which activate the stretch reflex. Thus, the muscle spindles in those muscles are stretched. Afferent impulses are evoked, and the muscles contract so that the pull of gravity is counterbalanced. Since the intrafusal muscle fibres of the muscle spindle can be activated from higher centres via the γ fibres, their receptors may be more or less prone to respond to a stretch. A feeling of happiness, alertness, or attention can increase γ activity, whereas unhappiness, drowsiness, or lack of attention can reduce the activity (Åstrand et al., 2003). In this way, part of the relationship between an individual's attention induced by processing a reaction task and posture may be explained.

However, the multi-choice reaction task induced only the initial decrease of COP velocity, which was followed by its slight increase in the end of the three-minute test. According to the inverted-U principle (Schmidt, Wrisberg, 2004) it may be assumed that increased arousal improves postural stability only to some point (in this case, 2:15 min), after which its further increase may be disadvantage. This assumption is in accordance with the findings of Tomporowski and Ellis (1986), showing that when a cognitive and an exercise task are executed together, there is an initial improvement of performance consistently followed by its decrease when the complexity of one of the two tasks increases. It would be interesting to investigate whether prolongation of the test or overloading the cognitive system by increasing task complexity would alter postural stability.

Increase in COP variables toward end of the test may be also explained by increased fatigue of lower limbs that was reported by examined subjects. In such cases, the attentional demand for maintaining an upright posture increases (Vuillerme et al., 2002). According these authors, muscular fatigue may put the individuals at higher risk of falling, especially when engaging in concurrent task.

Besides fatigue, it is known that injury, pathology or aging could impose greater reliance upon the cognitive levels of postural control. For instance, a reduced peripheral sensibility caused by diabetic neuropathy increases the attentional demand necessary for regulating gait (Courtemanche et al., 1996).

In contrast, specific training in gymnasts has been found (Vuillerme, Nougier, 2004) to decrease dependence on attentional processes for regulating postural sway during unipedal stance with respect to non-gymnasts. Rendering postural control less cognitively dependent may allow the gymnasts to pay more attention to the components of their performance. The efficiency of 6-weeks of balance exercises performed concurrently with reaction tasks in basketball players on neuromuscular performance, including improvement of agility performance and dynamic balance has also been proven (Zemková, Hamar, 2008). Similarly, task-oriented proprioceptive exercise (subject has to hit, as fast as possible, the target appearing randomly in one of the corners of the screen by horizontal shifting of COM while standing on unstable spring-supported platform equipped with PC system for feedback monitoring of COM movement) has been found (Zemková, Hamar, 2008) to enhance neuromuscular function, enabling more rapid postural sway adjustments in altered surface conditions.

Such exercise programs can have a great impact on the improvement of both balance and cognitive function in individuals who are at higher risk of accident and injury, such as some athletes, workers and the elderly. Particularly in balance-impaired older adults, the ability to maintain postural stability can be affected by the performance of concurrent cognitive task (Shumway-Cook et al., 1997). According these authors, the inability to allocate sufficient attention to postural control in multitask conditions is a contributing factor to imbalance and falls in older adults. For these individuals, balance exercises performing concurrently with reaction tasks seem to be promising. However, further investigations are needed to provide scientific guidelines concerning optimal duration and intensity of these exercises.

Conclusion

There is a greater increase in multi-choice than simple reaction time during balancing on the wobble board. It means that dynamic balance conditions may negatively affect the performance of a concurrent secondary cognitive task.

In contrast, postural stability improves when performing a secondary RT task. This effect is more evident for multi-choice that simple responses, though with prolongation of the test a slight increase in COP velocity may be observed. These findings indicate that reaction tasks can have positive effects on postural control.

Hence, having to deal with two tasks at the same time, both of which require controlled processing, can have different effects on a person's performance, depending on the task specificity.

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