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The influence of dual-tasking on postural control in young adults

A influência da dupla tarefa no controle postural de adultos jovens

La influencia de doble tarea en el control postural de adultos jóvenes

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ABSTRACT | The aim of this study was to investigate the influence of dual-tasking on postural balance in young adults. Participants were 20 college students (10 men and 10 women) with a mean age of 25 years. Postural balance was evaluated by the Sensory Organization Test (SOT), using the Smart Equitest™ NeuroCom® International, which evaluates the individual's ability to use the different systems of postural control (somatosensory, vestibular and visual) to keep in balance in the 6 conditions of sensory conflict presented by the system. The subjects were evaluated while single-tasking (maintaining balance) and dual-tasking (maintaining balance in conjunction with cognitive mental calculation task) in randomized order. Balance was measured by using the balance score, comparing the angular differences between the maximum anterior and posterior displacements. The Wilcoxon test with significance level of p≤0.05 was used to compare the mean scores of balance between the situation with and without dual task. The balance scores in SOT conditions were analyzed and demonstrated statistically significant differences in condition 1 (eyes open, fixed platform and visual surroundings; p=0.018) and condition 6 (eyes open, platform swings and fixed visual surroundings; p=0.008), with reduced balance when dual-tasking in both conditions. The results showed that while performing dual tasks, consisted of four arithmetic operations, the posture control is negatively affected, resulting in a greater oscillation of the subjects. Thus, the complexity of the secondary task may have been the main reason for the lower balance scores found.

Keywords | Postural Balance; Cognition; Young Adult.

RESUMO | O objetivo deste estudo foi verificar a influência da dupla tarefa no equilíbrio postural de adultos jovens. Fizeram parte do estudo 20 universitários (10 homens e 10 mulheres) com idade média de 25 anos. O equilíbrio postural foi avaliado pelo Sensory Organization Test (SOT), utilizando o Smart Equitest™ da NeuroCom® International, que avalia a habilidade do indivíduo para usar os diferentes sistemas do controle postural (somatossensorial, vestibular e visual) para se manter em equilíbrio nas 6 condições de conflito sensorial apresentadas pelo sistema. Os sujeitos foram avaliados em tarefa única (manutenção do equilíbrio) e dupla tarefa (manutenção do equilíbrio em conjunto com tarefa cognitiva de cálculo mental), de modo randomizado. O equilíbrio foi mensurado através do escore de equilíbrio, comparando diferenças angulares entre os deslocamentos anterior e posterior máximos. Foi utilizado o teste de Wilcoxon com nível de significância p≤0,05 para comparar as médias dos escores de equilíbrio entre a situação sem e com dupla tarefa. Os escores de equilíbrio nas condições do SOT evidenciaram diferença estatisticamente significativa na condição 1 (olhos abertos, plataforma e entorno visual fixos; p=0,018) e na condição 6 (olhos abertos, plataforma oscila e entorno visual fixo; p=0,008), com redução do equilíbrio com a

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dupla tarefa em ambas. Os resultados mostraram que durante a dupla tarefa, composta pelas quatro operações aritméticas, o controle postural é influenciado negativamente com maior oscilação dos sujeitos. Assim, a complexidade da tarefa secundária pode ter sido o principal motivo para os menores escores de equilíbrio encontrados.
Descritores | Equilíbrio Postural; Cognição; Adulto Jovem.

RESUMEN | Este artículo tuvo por objetivo verificar la influencia de doble tarea en el equilibrio postural de adultos jóvenes. Se han hecho parte del estudio 20 universitarios (10 hombres y 10 mujeres) con promedio de edad de 25 años. El equilibrio postural se evaluó por el Sensory Organization Test (SOT), con uso del Smart Equitest™ de la NeuroCom® International, el que evalúa la habilidad del sujeto en el uso de los distintos sistemas de control postural (somatosensorial, vestibular y visual) con el fin de mantenerse en equilibrio en las 6 condiciones de conflicto sensorial presentadas por el sistema. Se han evaluados los sujetos en una sola tarea (manutención del equilibrio) y de doble tarea (manutención del equilibrio en relación con la tarea cognitiva de cálculo mental), del modo aleatorizado. Se midió el equilibrio a través de la puntuación de equilibrio, al comparar diferencias angulares entre el desplazamiento anterior y posterior máximos. Se ha hecho la prueba de Wilcoxon con el nivel de significancia p≤0,05 para comparar las medias de las puntuaciones de equilibrio entre la situación sin o con doble tarea. Las puntuaciones de equilibrio en las condiciones del SOT han mostrado diferencias estadísticas significativas en la Condición 1 (ojos abiertos, plataforma y entorno visual fijos; p=0,018) y en la Condición 6 (ojos abiertos, plataforma que oscila y entorno visual fijo; p=0,008), con la reducción de equilibrio con doble tarea en ambas las condiciones. Los resultados mostraron que durante la doble tarea, que consiste en las cuatro operaciones aritméticas, el control se influyó negativamente con mayor oscilación de los sujetos. De esa manera, la complejidad de la tarea secundaria puede ser la principal razón para las menores puntuaciones de equilibrio encontradas.
Palabras clave | Equilibrio Postural; Cognición; Adulto Joven.

INTRODUCTION

The key point to achieve good motor performance is to make motor behavior automatic, so that they can be unconsciously performed[1]. Automation is defined as a skill that is performed with little demand for attentional resources referring to the performance of a skill[2].

These concepts can also be applied to stability skill and postural control, where quick corrective actions, called automatic postural responses, are essential in order to counter destabilizing effects from mechanical disturbances during daily activities[3].

Information from multiple sensory systems (somatosensory, visual and vestibular) are integrated through the motor control system to guide and align position among the body segments and their location in relation to the external environment[4]. Based on this information, the central nervous system produces postural strategies that include muscle synergies, joint movement patterns, contact forces and torques[5,6].

Postural control is defined as being the body's ability to maintain its position, in order to provide balance and orientation. Being in balance is the ability to maintain a center of gravity (COG) within the limits of the support base[7].

Although balance, posture and gait have been considered automatic and subconscious tasks, some studies[8-12] have suggested that attentional resources are needed to maintain balance, which vary according to the task, age and the individual's sensorimotor skill. The dual-task paradigm is used to study balance/posture related to cognition, with posture usually being considered the primary task, and any activity that requires cognitive processing being the secondary task[13].

For an adult, one of the challenges in modern life is being able to perform several tasks in a relatively short period of time. Thus, performing two or more tasks, such as driving and talking[14], walking and talking[15], or listening at the same time as writing[16] form dual-task cognitive situations, where attention is divided. Studies[17-20] have been performed with the objective of concurrently evaluating postural balance along with a cognitive task, considering that in most everyday situations humans perform other tasks whilst standing.

The dual-task paradigm is the method used to study automation, the hemispheric locus and the structural independence of the processes, which are hypothetically the basis for reaching a good performance[21].

In the dual-task paradigm, automation refers to the ability of a person to perform some tasks concurrently and with little interference. Reduced performance in a dual task condition is known as dual-task interference[22]. Attention refers to the ability of an individual to process information[8]. Attentional limitation while performing a dual-task or dual-task interference is explained by some theories, such as the single-channel, capacity-sharing and unitary-resource capacity theories[22].

These theories have are connected with motor control and motor learning[23]. The ability to perform a second task at the same time as a first is crucial during most daily activities when a motor act is involved, such as when humans simultaneously walk and talk or move an object from one place to another while observing the surrounding environment. The current paradigm from dual-task interference states that introducing a second task during a motor or cognitive performance would lead to a possible competition between available attentional resources, which could cause a decrease in performance in one of the tasks being executed[24].

Changes are expected in body oscillation when performing dual-tasks, due to the competition for the attentional resources[25]. These changes are most evident in elderly individuals due to their decreased postural stability[8,10,26], and may contribute to postural instability and falls, be they in elderly individuals with balance disabilities[27,28], those with cognitive deficits[29,30] or healthy elderly individuals[31].

Dual-task studies in young individuals have shown a relationship between balance and cognition. Kerr, et al.[32] investigated the interaction between postural regulation and spatial processing at 24 universities. University students performed tasks that involved spatial cognitive memory and verbal cognitive memory while seated or while standing with closed eyes in a Romberg "tandem" position. By means of the center of pressure, the authors concluded that the balancing task only affected spatial memory performance, and that there was a similar postural oscillation while the dual-task was performed.

Similarly, Lajoie, et al.[33] reported that postural control requires attentional resources and that this demand increases along with the postural task's level of difficulty, thereby concluding that balance control requires the continuous adjustment and integration of sensory signals. Additionally, concurrent tasks also have an influence on gait parameters[34] and recovering postural control[35] in young adults.

Some studies[36,37], while using NeuroCom's® Smart Equitest™, did not find any changes in the postural control of young adults in the standing position while performing a second task (auditory). Yardely, et al.[36] evaluated postural oscillation with and without using dual-task in subjects with vestibular disorder and in healthy young adults; they found that young subjects concurrently performing a second task did not modify their pattern of body oscillation. Shumway-Cook and Woollacott[37], during a study with young and elderly subjects involving different sensory conditions, with opened and closed eyes, on a stable and unstable surface, also concluded that the addition of a second task, regardless of the sensory condition, did not modify the pattern of postural oscillation in the young adults.

Brown, et al.[25] investigated the responses of young adults and elderly individuals to unexpected movements of a platform without a secondary task or while performing a math task (counting backwards in threes). The authors concluded that attentional demand is greater in the elderly than in young people when recovering balance. Performing the math task induced the subjects to prematurely perform a step strategy.

In spite of the fact that that previous studies have been done, there is still little information as regards the dependence of attentive mechanisms in the postural control in young individuals, in addition to the previously performed studies having presented conflicting results. Better understanding is necessary regarding dual-task interaction in postural control, especially with a view to make a helpful contribute, in terms of new evaluation and treatment approaches, to individuals possessing some disability in these skills.

Given the aforementioned, this article's objective was to verify the influence of the dual-task on body balance in young adults. It is the authors' hypothesis that performing a cognitive double-task will result in greater postural instability in young adults, which may suggest that the postural control in young adults is dependent on their attentive capabilities.

METHODOLOGY

This study was of an observational, transversal nature, performed at the Center for Health Sciences and Sports (CEFID) at the State University of Santa Catarina (UDESC) and was approved by the Ethics Committee under Protocol no. 05815512.0.0000.0118, which followed the resolution set out by the Brazilian National Health Council.

Subject

20 students took part in the study (10 men and 10 women), who were recruited at the Center for Health Sciences and Sports at UDESC by non-probabilistic intention[38] and by their availability. The participants had an average age of 25 (±4) years. The patients who agreed to participate in the research signed a Term of Free and Informed Consent. The adopted eligibility criterion were: healthy individuals from both genders, aged from 20 to 30 years, with no recent neuromusculoskeletal trauma or injury recent (in the preceding six months), in addition to having no otoneurological complaints. The study subjects who were excluded were those who had diseases associated with posture and injury or musculoskeletal deformities, that were evident upon inspection, and/or those who were undergoing physiotherapeutic treatment.

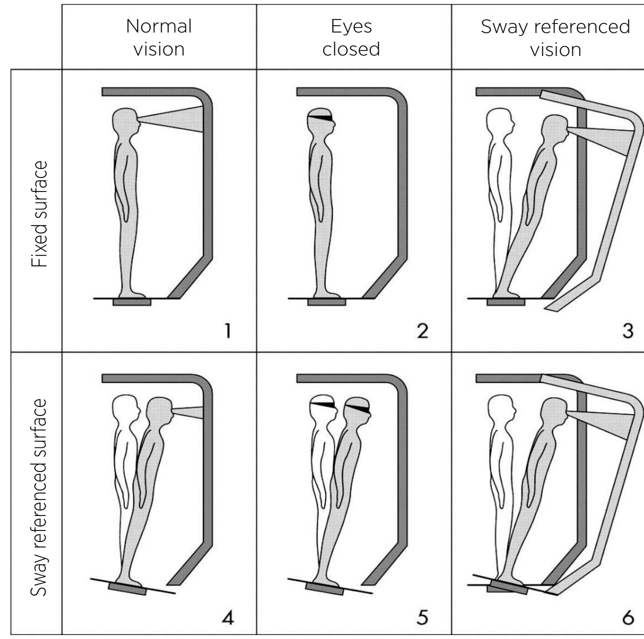

Figure 1. Sensory Organization Test
Source: NeuroCom® International website (http://resourcesonbalance.com/program/role/cdp/protocols.aspx)

Methods and materials

Postural balance was evaluated by way of a Sensory Organization Test (SOT), using the Smart Equitest™ from NeuroCom® International. The SOT evaluates an individual's ability to use various postural control systems (somatosensory, vestibular and visual) to maintain balance in a bipodal position, under sensory conflict conditions. Sensory conflicts were produced by moving the force platform and/or the visual environment in response to the subject's oscillation.

The SOT was made up by 6 conditions: (1) eyes open, fixed platform and visual surroundings; (2) eyes closed and fixed platform; (3) eyes open, fixed platform and oscillating visual surroundings; (4) eyes open, oscillating platform and fixed visual surroundings; (5) eye closed and oscillating platform; and, (6) eyes open and oscillating platform and visual surroundings, as shown in Figure 1. The eyes closed conditions were created by blindfolding the subjects with a mask.

The data collections were performed in the order of condition 1 to condition 6. Each condition was repeated 3 times, for 20 seconds for each repetition. The data were collected by means of two AMTI® force platforms with a 100Hz acquisition frequency. Balance was measured by means of a balance score, with which angular differences were compared between the subjects' maximum anterior and posterior maximum movements. The result was expressed as a percentage between zero (fall) and 100 (maximum stability).

Each subject involved in the research performed both tasks: single-task (maintaining balance) and dual-task (maintaining balance along with a cognitive mental calculation task), in which the subject must solve and then announce the response to the arithmetic equations. The order in which the tests were performed was randomized by a random draw, in which the participant chose a number from 1 to 40, which corresponded to the random order of the tests, this was done in order to verify how and with which test the data collection would be initiated. To perform the test, the participant remained in a bipodal stance on the force platforms, barefoot and with their arms relaxed down the body. The use of corrective visual lenses was permitted wherever necessary. During the procedure, all the subjects were advised to maintain an upright and stable posture, remaining as still as possible.

The arithmetic equations were developed by the researchers and contained four mathematical tasks, which were projected on a monitor located in front of the subjects. The subjects were instructed to answer the questions out loud and as fast as they could. After the subject delivered a response for one equation, another random equation was projected onto the monitor. For the eyes closed tests (conditions 2 and 5), the equations were communicated by the researchers in a loud and clear voice. All the equations followed the same order (sum, subtraction, multiplication, and division) using numbers from 1 to 20, for example: (8+15–7×3÷2).

Statistical analysis

The Shapiro-Wilk test showed no Gaussian distribution in the data, so the Wilcoxon matched-pairs test was used in order to compare the means from the balance scores between the situation with and without dual-task. The adopted significance level was 5%. The Statistical Package for the Social Sciences (SPSS) software for Windows 20.0 was used to perform the analyses.

RESULTS

Table 1 shows the anthropometric data from the subjects evaluated during the research.

Table 1. Anthropometric characteristics of the subjects

Variables	Male (n=10)	Female (n=10)	Total
Age (years)	24.5 (±4.5)	25.9 (±3.5)	25.2 (±4.0)
Weight (kg)	68.66 (±5.6)	59.46 (±4.7)	64.06 (±6.9)
Height (m)	1.74 (±0.07)	1.62 (±0.06)	1.69 (±0.08)
BMI (kg/m^2)	22.65 (±1.7)	22.39 (±1.1)	22.52 (±1.4)

BMI: Body Mass Index

As shown in Figure 2, the balance scores under conditions 1 (eyes open, fixed platform and visual surroundings) and 6 (eyes open, oscillating platform and visual surroundings) showed a statistically significant difference between the condition with and without the dual task. In condition 1, they were 94.58% (single task) and 92.13% (dual task), with p=0.018; in condition 6, they were 75.17% (single task) and 65.90% (dual task), with p=0.008. In the other conditions from the SOT there were no differences between the two conditions.

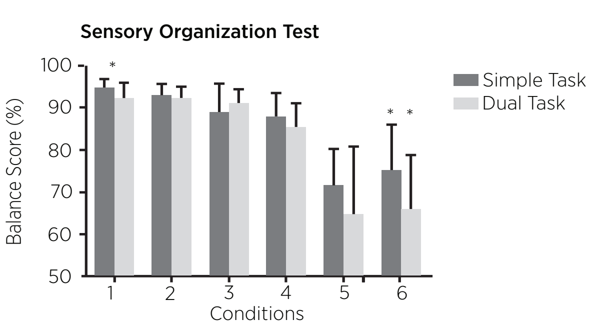

Figure 2. Balance score between the conditions of the SOT
* Condition 1 – p=0.018
* Condition 6 – p=0.008

DISCUSSION

This study's findings showed the influence that the dual task had on balancing situations 1 and 6, evaluated by the SOT, which manifested themselves in lower balance scores, i.e. greater body oscillation during the cognitive task. It is the belief of the research team that competition for attentional resources between postural control and the cognitive task, during central nervous system processing, may be responsible for the greater oscillation observed in these situations.

Shumway-Cook and Woollacott[37] affirm that attention is the processing capacity of an individual and the performance of any given task that requires a certain portion of said capacity. Due to this capacity being limited, if two tasks are performed simultaneously and require a lot of attention, the performance in one or in both decreases. The simultaneous performance of a cognitive and postural task can have a harmful effect on balance control due to a reduction, or misallocation of attentional resources.

According to McDowd[39], the division of attention can be influenced by several factors, such as: individual variability, familiarity with the two tasks, fatigue, anxiety, age and experience in the examined condition. Due to the fact that SOT is a sequential test, which always begins with condition 1, the increased oscillation in the first condition during the dual-task can be explained by the subject's familiarity with the tasks.

Whereas in condition 6, the lesser balance can be justified by the complexity of the postural control task, given that in this condition the afferent information from the visual and somatosensory systems are conflicted due to the vestibular system having a greater participation in balance. Along with the increased perception for maintaining postural control, there is a reduction in the central nervous system's performance in terms of performing other tasks[22]. This demonstrates how important the integrity of the cognitive functions is for maintaining postural control in young adults.

Kerr, Condon, and McDonald[32] concluded that in young adults, postural control is dependent on attention, thereby corroborating the results from this study. Additionally, they reported that postural control is not automatic and that the simultaneous performance of a second task requires executive control, requiring attentional demands that would be otherwise be targeted towards balance.

With this in mind, some theories provide assistance in terms of understanding the interaction between postural control and the cognitive task. The single-channel theory (bottleneck) suggests that parallel processing can be impossible for certain mental operations. When two tasks require the same mechanism at the same time, there is a "bottleneck", and the performance of one or both tasks can be affected. Not forgetting the capacity-sharing theory, which assumes that the processing capabilities or mental resources are divided between the tasks, meaning that there is limited capacity for processing information. Therefore, there is decrease in performance or in ability when the attentional capacity limit is reached. The unitary-resource capacity theory assumes that attentional resources are limited, albeit flexible, and that attention is selective[22], with concurrent tasks demanding a overload in central processing or mental effort[40]. Thus, it is reasonable to say that postural control and the concurrent mathematical processing were competing for the same attentional resource, thereby slowing down performance.

Unlike the previously mentioned points, Hunter and Hoffman[41] evaluated the influence of a cognitive task (arithmetic sum) on the postural control of 30 young adults using a pressure platform, there was an observed decrease in body oscillation during the cognitive task, thereby indicating better balance.

In the same context, Ross, et al.[19] compared the effect of a dual-task on the balance of healthy young adults, namely through evaluating the postural control of thirty individuals (14 men and 16 women) utilizing the SOT. The task chosen was the Procedural Reaction Time (PRT) task, during which the subjects' balance was evaluated by pressing the left or right button of a mouse according to number that appeared on the screen. The study also showed decreased body oscillation during the performance of the dual-task.

Similarly, Resch, et al.[42], while using the SOT, evaluated the balance and the reaction time of 20 students (10 men and 10 women), aged 20 (±1.8) years old, with and without a cognitive task. The task consisted of pressing the right button of a mouse when numbers appeared on the computer screen, and the left button when letters were shown. The results showed an increase in balance scores during the cognitive task, i.e., the subjects presented better posture control during the dual-task.

These examples have differing results from those found during this study, as the subjects showed decreased postural control during the dual-task, thereby evidencing greater body oscillation. This is due to the competition that exists between the cognitive functions and postural control by the limited attentional capacity, which results in one of the task's performance being compromised. According to Woollacott and Shumway-Cook[8], when the cognitive task is performed while the subject is in an upright posture, attention tends to be split between this task and the ability to maintain postural control.

For Huxhold, et al.[43], performing a motor task with relatively low cognitive demand can benefit postural control, leading the individual to keep focus on that type of control, while a high cognitive demand tends to undermine the regulation of body oscillation.

Prado, et al.[17] investigated postural control while performing a working memory task in 24 subjects, these being 12 young individuals (22-39 years) and 12 active elderly individuals (65-75 years), using a force platform. The authors used visual tasks such as inspection (looking at close and distant blank targets) and demand (silently reading a text and counting the appearance of certain letters, stating the result at the end of the data collection). The close targets were positioned 0.4m from subject, with the the distant targets being 3m away. The results reinforce the idea that secondary tasks do not necessarily lead to a decrease in body oscillation.

Moreover, the presence of visual information seems to increase compensatory postural demand when the postural task is more difficult[44].

However, upon analyzing the CoP in conditions 2 and 5 with dual-task, there was no statistically significant difference found. These results differ from the findings of other studies, where removing the visual information and adding a cognitive task increased the CoP oscillation in the individuals[45].

This study's findings also showed that there is no significant interference from the dual-task in conditions 2,3,4 and 5 of the SOT. In young adults, this interference appears to be small, but increases when the postural tasks become more challenging and more complex cognitive tasks are used[8], as was the case in condition 6 of the SOT, in which performing the postural task was more difficult.

One limitation of this study was not measuring the response time nor the accuracy of the cognitive task during postural control task. Such a measure would have been interesting to find out whether there was a detrimental effect on both tasks and also to discover which task had greater change during the procedures.

Thus, it is necessary to carry out future studies in order to evaluate the influence of dual-task on the postural control and cognitive processing of subjects, as well as to assess cognitive tasks at different levels of difficulty.

It is believed that a greater number of studies are necessary to better understand the interaction between postural control and duel-task, because this evaluation, by means of attentive mechanisms may be used in future rehabilitation programs in order to provide beneficial effects on postural control, as well as for treating individuals with these skill deficits.

CONCLUSION

The results found during this study make it possible to conclude that the performance of young adults during the sensory organization test was less than during the dual-task under conditions 1 and 6, this was evidenced by the significant decrease in balance scores whist under these conditions, thereby suggesting a reliance on attentive mechanisms for postural control when a complex cognitive task is added.

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