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ORIGINAL ARTICLE

Sensory and motor differences between young and older adults: somatosensory contribution to postural control

Diferenças sensoriais e motoras entre jovens e idosos: contribuição somatossensorial no controle postural

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Abstract

Objectives: The aim of this study was to compare the performance of the sensory and motor systems and the contributions of possible differences to postural control. **Methods:** Twenty older adults (68.9±3.7 years of age) and twenty young adults (21.9±2.1 years of age) underwent visual, somatosensory (tactile and kinesthetic sensitivity), motor tests (joint torque and muscle activation latency) and postural control assessments (upright semi-tandem posture). **Results:** MANOVA and ANOVA indicated that older adults had a poorer performance in the sensory tests: visual acuity (p=0.001), visual contrast sensitivity (p=0.009), tactile sensitivity (p<0.001) and kinesthetic sensitivity of the knee (p<0.001) and ankle (<0.001); and in the motor tests: female (p=0.010) and male (p<0.001) knee flexion torque; female (p=0.002) and male (p<0.001) knee extension torque; female (p=0.029) and male (p=0.006) ankle dorsiflexion torque; female (p=0.004) and male (p=0.004) ankle plantar flexion torque; and muscle activation latency (p<0.001). The older adults also had greater body sway amplitude on the anterior-posterior direction (p=0.035). Multiple regression analysis revealed that perception of passive motion was the only variable that contributed to greater body sway on the anterior-posterior direction among older adults (R^2=0.142; p<0.05). **Conclusions**: There are differences in sensory and motor performance between young adults and older adults, and attention should be directed toward the contribution of the proprioceptive system to postural control among older adults.

Key words: proprioceptive system; postural control; aging.

Resumo

Objetivos: Comparar o desempenho dos sistemas sensoriais e motor entre jovens e idosos e identificar as contribuições das possíveis diferenças para o controle postural. **Métodos:** Vinte idosos (68,9±3,7 anos de idade) e 20 jovens (21,9±2,1 anos de idade) realizaram testes visuais; somatossensoriais (sensibilidade cutânea e cinestésica); motores (torque articular e latência de ativação muscular) e de controle postural (postura ereta em semi-tandem). **Resultados:** As análises de variância (ANOVAs) e as análises de multivariância (MANOVAs) indicaram desempenho inferior dos idosos nos testes sensoriais: acuidade visual (p=0,001); sensibilidade ao contraste visual (p=0,009); sensibilidade cutânea (p<0,001); sensibilidade cinestésica de joelho (p<0,001) e tornozelo (<0,001), e motores: torque em flexão de joelho feminino (p=0,010) e masculino (p<0,001); extensão de joelho feminino (p=0,002) e masculino (p<0,001); dorsiflexão de tornozelo feminino (p=0,029) e masculino (p=0,006), flexão plantar de tornozelo feminino (p=0,004) e masculino (p=0,004) e latência de ativação muscular (p<0,001). Os idosos também apresentaram maior oscilação corporal na direção ântero-posterior (p=0,035). Análise de regressão múltipla revelou que a percepção ao movimento passivo foi a única variável que contribuiu para a maior oscilação corporal na direção ântero-posterior em idosos, R^2=0,142, p<0,05. **Conclusões:** Diferenças no desempenho sensorial e motor ocorrem entre jovens e idosos e atenção deveria ser direcionada para a contribuição do sistema proprioceptivo para o controle postural de idosos.

Palavras-chave: sistema proprioceptivo; controle postural; envelhecimento.

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Introduction

The increase in the older adult population has been occurring at unprecedented rates. Projections indicate that by 2050 the elderly population will reach 2 billion people worldwide[1]. Along with these demographic changes, diseases associated with ageing will represent a burden to society, for example by an increase in demand for health services.

Because older adults demand more from the health service infra-structure, efforts have been made to understand the factors that contribute to a healthy ageing. In addition to biological factors, diseases and external factors may lead to negative functional consequences in these individuals. According to the International Classification of Diseases (ICD-10)[2], falling is one external factor that represents a major problem for older people because of its consequences, such as lesions in softer parts of the body, long bedridden periods, hospitalization, institutionalization, increased risk of diseases, fractures, impairment and even death. Furthermore, the fear of falling again may reduce the activity level of older individuals, leading to the immobility syndrome[3].

The substantial increase in falls with ageing has been attributed to a decline in the performance of the postural control system[4-6]. Although falling represents the most dramatic consequence of changes in postural control, even older people who are capable of performing their daily activities in an independent way may have a significant reduction in postural control, which will become evident only after a fall. The factors accounting for the decline in postural control are still unclear, and some understanding of this issue might, among other actions, facilitate the planning of specific programs focused on avoiding falls among older adults.

Postural control can be defined as the process by which central nervous system generates muscle activity patterns required to regulate the relationship between the center of body mass and the base of support[7]. According to Horak and Macpherson[8], the functional goals of postural control, i.e. orientation and postural balance, stem from an intricate and dynamic relationship between sensory information and muscle activity. In older adults, these components might be altered by changes in sensory and motor systems that take place over the years.

Changes in sensory and motor systems that affect postural control in older adults have been broadly investigated[9-12]. However, there are some inconsistencies in the literature, possibly due to the lack of control of the population under study. For example, diseases associated with ageing are present in a great part of the older adult population and they can explain the sensory and motor decline observed in these individuals. When dealing with postural control among older adults, the characteristics of the sample being studied deserve special attention, so that the consequences of ageing (i.e. sensory and motor decline) can be discriminated from those of diseases associated with ageing. Nevertheless, difficulties with this discrimination is a problem faced by health professionals, representing a barrier to the development of specific preventive and rehabilitation programs. Thus, it is important to examine the probable changes originating from ageing and how they may contribute for the lack of postural control among older adults. The goals of this work were to identify sensory and motor differences between young and older adults and to evaluate their contribution to posture control in healthy individuals.

Methods

Participants

Twenty people aged from 65 to 76 years (68.9±3.7) formed the group of older adults (OAG), and 20 people aged from 18 to 26 years (21.9±2.1) formed the group of young adults (YAG). The older adults did not take part in any regular and systematized physical activity program in the previous two years. In order to evaluate the current level of physical activity of the older adult participants, the Modified Becke Questionnaire for Older Adults[13] was applied. The questionnaire has been validated by Mazo et al.[13] and provides a score for the energy spent in three groups of activities: household activities, sports activities, and leisure activities. The questionnaire was applied to ensure that participants were not physically active, since this would influence the results of other tests. Questionnaires evaluating the history of falls and dizziness were also applied to make sure that participants were not fallers and did not present any symptom indicating dysfunction of the vestibular system, respectively. These questionnaires were developed by Professor Perracini, from Universidade Cidade de São Paulo (UNICID), São Paulo (SP), Brazil, and provided a more elaborated anamnesis about the falling and dizziness history of the older adult participants. Finally, the Mini Mental State Examination[14,15] was applied to confirm the absence of cognitive dysfunction. None of the participants claimed to suffer from any type of pain or disease, or any visual, musculoskeletal and/or neurological dysfunction. Additionally, none of them reported using benzodiazepines or antidepressant medication, or using prostheses or orthoses.

Procedures

The participants underwent sensory, motor and postural control assessments carried out by a single evaluator. In some cases, assistance from a second researcher was required to start up the commands in the computers used during the tests (e.g. Servomotor, Optotrak). Sensory assessments comprised visual (acuity and contrast sensitivity tests) and somatosensorial evaluations (tactile sensitivity and sensitivity to passive motion tests). Motor assessments consisted of measurements of joint torque and muscular latency following support surface translation. Postural assessments consisted of measurements of body sway while the participant maintained a semi-tandem upright posture.

As suggested by Owsley[16], visual acuity and sensitivity to contrast would be appropriate measures of visual performance for most people. In the present study, visual acuity was measured by the Snellen's Chart[12] and its score corresponded to the number of the row in which the participant had been able to get right at least 2/3 of the optotypes. Scores in the scale range from 0.1 to 1, with higher values representing better visual acuity. For the assessment of visual contrast sensitivity, a computer test based on the TwoDocs Color Test[17] was developed. During this test, participants visualized arrows pointing towards different directions in a computer screen. With every optotype, there was a contrast reduction of 0.15 logarithmic units, corresponding to the following contrast percentages: 100, 70, 50, 36, 25, 18, 9, 6, 4, 3, 2 and 1%. Visual contrast sensitivity was expressed in decimal numbers corresponding to the minimum contrast percentage perceived by the participant, with smaller percentages representing better sensitivity to contrast.

Tactile sensitivity (exteroception) was assessed by the Semmes–Weinstein pressure aesthesiometer kit[11,12], which consists of six monofilaments that exert different pressures on the skin (ranging from 0.05 to 300 grams of force), with the perception of lower pressure representing better tactile sensitivity. The test was carried out on the plantar surface of the first metatarsophalangeal joint of participant's right foot[18] (Figure 1).

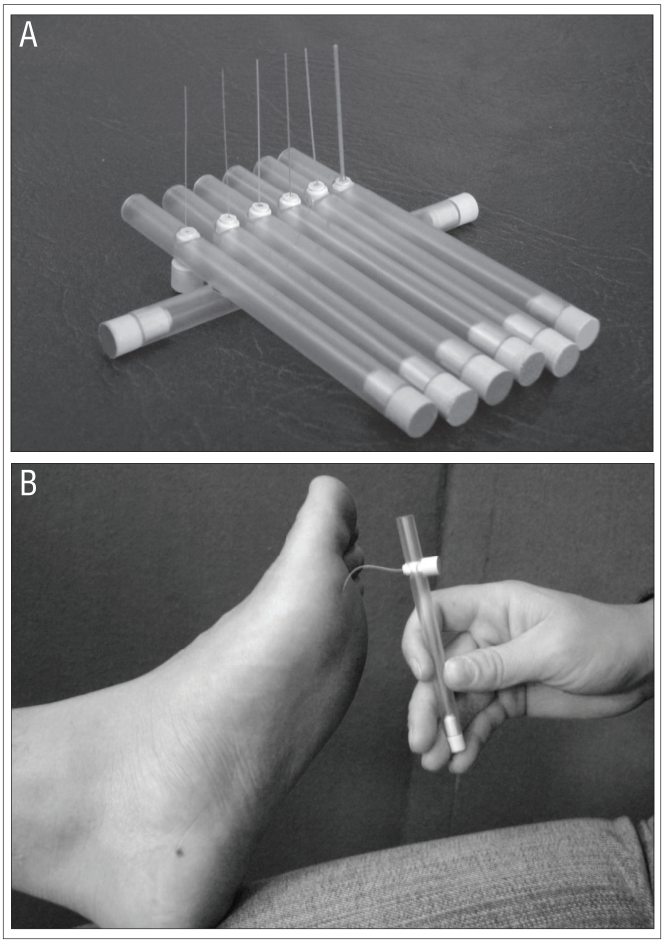

Figure 1. Aestesiomether kit (Semmes-weinstein Monofilaments) (A) and procedure of tactile sensitivity assessment (B).

The sensitivity to passive motion test assessed the threshold of passive motion detection (proprioception) of the ankle and knee joints. An equipment based on the CPM (Continuous Passive Motion – Stryker – Leg Exerciser)[19] was especially developed for this experiment. To test the ankle joint, the participant was placed in a sitting position with the right foot resting onto a tiltable support surface, which carried out ankle plantar and dorsal flexion at 0.5 degrees/second[19] in an alternate manner. To test the knee joint, the participant was placed in a sitting position with the legs hanging, and the right knee was flexed and extended in an alternate fashion by an apparatus connected to the posterior part of the participant's shoe. The participant was instructed to maintain their eyes closed and to activate a gadget kept in their hand as soon as any leg or foot movement was noticed. For this test, some noise was added to the ambient (i.e. ventilators with a high level of noise) to eliminate the possibility that a sound coming from the equipment was used as an auditory cue indicating that the movement had begun. The dependent variable was the displacement between the initial position and the position in which the movement was detected and interrupted by the participant. This displacement was measured in degrees by a motion analysis system (OPTOTRAK 3020, NDI, Inc.), with smaller angle displacements representing better sensitivity to passive motion.

The evaluation of the capacity to produce joint torque followed the guidelines of the American Society of Exercise Physiologists (ASEP)[20] and was carried out by a especially developed device. To assess the knee extension torque, the participant was placed in a sitting position (knee semi-flexed around 60 degrees from full extension) and was instructed to perform an isometric knee extension contraction. The procedure was repeated to assess the knee flexion torque (knee semi-flexed around 30 degrees from full extension). To assess the ankle torque, the joint was positioned at around 90 degrees between the leg and foot segments and the participant was instructed to perform isometric ankle contractions, alternating between dorsal flexion and plantar flexion. A load cell allowed the quantification of the force (Kg) exerted perpendicularly to the lever arm (Weighing indicator Model LD1050, brand Líder). The torque (Nm) was calculated according to the force exerted and the distance between the rotation axis and the point where the force was applied.

To assess the muscular latency, the participant was placed on a moving platform in an upright position. Movements in an anterior-posterior direction were produced by a servo-motor mechanism consisting of a controller (Compumotor – APEX6151), a stepper motor (Compumotor - Model N0992GR), an electric cylinder (Compumotor – Model EC3-X3) and a specific software to control de system (Compumotor – Motion Architect for Windows). The platform movement produced 3.6cm displacement with peak velocity of 16.5 cm/s[21], which were controlled by the motion analysis system. Bipolar surface electrodes were positioned on the tibialis anterior muscle. Latency was defined as the time elapsed between the beginning of platform movement and the beginning of muscle activation, with quicker muscle responses representing better (shorter) muscular latency.

In order to examine the performance of the postural control system in an upright position, the participants were asked to maintain a semi-tandem position as still as possible for 30 seconds, while staring at a 4.5cm diameter target placed at eye level and one meter away. An infrared emitter of the movement analysis system was fixed onto the participant's interscapular region in order to record the total body sway in the anterior-posterior and medial-lateral directions. To quantify the body sway, the mean amplitude was calculated by the variance of the body sway in the respective directions, with smaller values of sway representing better postural control.

Data treatment and computation were carried out, when applicable, by the MATLAB software (Math Works, version 7.0).

Statistical analysis

Before carrying out statistical analyses to verify possible differences between the groups, normality tests and tests for homogeneity of variances were performed and, when necessary, variables were transformed so that these prerequisites were met. To verify differences between the groups in variables measured on an ordinal scale (such as visual acuity, visual contrast sensitivity and tactile sensitivity), the Mann-Whitney U test was applied for each dependent variable.

Two MANOVAs were conducted to verify differences in sensitivity to passive motion between the groups. The first MANOVA included the factors 'group' (YAO and OAG) and 'direction' (flexion or extension), the latter being treated as a repeated measurement; angular displacements of the knee and ankle were used as dependent variables. The second MANOVA included the factors 'group' (YAO and OAG) and 'joint' (knee and ankle), the latter being treated as a repeated measurement; flexion and extension angular displacements were used as dependent variables.

Two MANOVAs were carried out to analyze the capacity of producing joint torque. One MANOVA was carried out for female participants and another for male participants. Their factors included 'group' (YAO and OAG) and knee and ankle joint torques (in flexion and extension directions) were used as dependent variables.

One ANOVA was carried out to verify possible differences in muscular latency between the groups. Two ANOVAs were also carried out to analyze possible differences in the maintenance of the upright posture, having as dependent variables the mean sway amplitude for the anterior-posterior and medial-lateral directions.

Finally, in order to identify the sensory and motor variables (dependent) which could explain the variance in postural control variables (independent), a stepwise multiple linear regression analysis was carried out. The variables of the sensory and motor assessments that were different between the groups were used as predicting variables.

When applicable, univariate tests and Tukey *post hoc* tests with Bonferroni adjustments were conducted (SPSS version 10.0). The level of significance was set at 0.05 for all analyses.

Before the evaluations were carried out, all participants signed an informed consent form approved by the Ethics Committee of the Institute of Biosciences of Universidade Estadual Paulista (UNESP), (Rio Claro (SP), Brazil, protocol n. 3571, June 27th, 2006).

Results

Means and standard deviations of the variables obtained in the sensory, motor and postural control assessments for each group are displayed on Tables 1-3.

Table 1. Mean and respective standard deviation (SD) values of the sensory variables for the young adult group (YAG) and for the older adult group (OAG) and statistical probability (p) obtained in the comparison between the groups.

Measure	YAG		OAG		p
	Mean	SD	Mean	SD	
Visual acuity	0.990	0.045	0.815	0.225	0.001*
Visual contrast sensitivity	0.010	0.000	0.013	0.005	0.009*
Tactile sensitivity (g)	0.20	0.43	2.47	2.89	<0.001*
Sensitivity to passive motion (º)					
Knee flexion	0.47	0.18	1.15	0.58	<0.001*
Knee extension	0.52	0.26	1.10	0.74	
Dorsal ankle flexion	0.51	0.17	1.17	0.63	<0.001*
Plantar ankle flexion	0.49	0.19	1.26	0.80	

*Significant difference between the groups ($p<0.05$).

Table 2. Mean and respective standard deviation (SD) values of the motor variables for the young adult group (YAG) and for the older adults adult group (OAG) and statistical probability (p) obtained in the comparison between the groups.

Mearure	YAG		OAG		p
	Mean	SD	Mean	SD	
Joint Torque Female (Nm)					
Knee flexion	74.73	17.00	54.61	12.79	0.010*
Knee extension	132.58	42.92	83.26	28.63	0.002*
Dorsal ankle flexion	48.96	16.27	33.63	10.11	0.029*
Plantar ankle flexion	220.99	51.58	151.99	40.23	0.004*
Joint Torque Male (Nm)					
Knee flexion	139.36	26.81	85.99	28.30	<0.001*
Knee extension	272.09	63.07	136.17	58.14	<0.001*
Dorsal ankle flexion	86.94	18.55	60.92	19.12	0.006*
Plantar ankle flexion	294.67	68.26	202.75	54.14	0.004*
Muscular Latency (ms)	80.81	9.59	100.76	16.17	<0.001*

*Significant difference between the groups ($p<0.05$).

All sensory and motor variables were different between the groups, with the OAG showing a lower performance in all sensory and motor evaluations when compared to the YAG. In the postural control test, the older adults swayed more than the young adults in the anterior-posterior direction, but there was no difference between the groups in relation to the medial-lateral direction.

Table 3. Mean and respective standard deviation (SD) values of the postural control variables for the young adult group (YAG) and for the older adults adult group (OAG) and statistical probability (p) obtained in the comparison between the groups.

Measure	YAG		OAG		p
	Mean	SD	Mean	SD	
MSA AP (cm)	0.24	0.07	0.33	0.14	0.035*
MSA ML (cm)	0.44	0.15	0.54	0.20	0.105

MSA AP: Mean sway amplitude on the anterior-posterior direction; MSA ML: Mean sway amplitude on the medial-lateral direction; *Significant difference between the groups ($p<0.05$).

Contribution of the sensory and motor variables for postural control

As all sensory and motor variables were different between the groups, all of them were included in the multiple linear regression analysis as predicting variables of the body sway. Although joint torques were significantly different between the groups in both directions (flexion and extension) and joints (knee and ankle), only some of them were chosen for this analysis, namely knee extension and ankle dorsal flexion torques. This decision aimed to use the same variables used in the study carried out by Lord, Clark and Webster[12]. For the sensitivity to passive motion, as there were no differences between the joints (knee and ankle) or between the directions (flexion and extension), the mean of the four variables was calculated and included in the analysis. In the postural control assessment, only the mean sway amplitude in the anterior-posterior direction was different between the groups, and for this reason it was included as a dependent variable in the regression model.

The multiple linear regression analysis revealed that the only variable that contributed significantly to the variance of the mean sway amplitude in the anterior-posterior direction was the sensitivity to passive motion, $R^2=0.142$, F(1.38)=6.290, residue=4.897, $p<0.05$. In this case, a greater angular displacement in the sensitivity to passive motion assessment was associated with a greater body sway while maintaining the upright posture.

Discussion

The present work shed some light on a number of aspects affecting postural control among older adults, particularly on how sensory and motor systems may contribute to a good postural control in this population. The methods used to establish a relationship between sensory and motor changes of the ageing process and changes in postural control were considered adequate, since all included participants were free of diseases associated with ageing. Besides, the same sample underwent the evaluations, which lent credibility to the investigation about the sensory and motor differences between young and older adults, and their possible consequences for postural control. Because the present study had a cross-sectional design, one cannot claim that the differences found are strictly related to the natural process of ageing, although this relation is possible. A longitudinal study would be the most appropriate design to infer causality, but this procedure would require an overly long follow-up period, rendering this research infeasible.

The assessment of the sensory and motor systems showed that young and older adults have different performances. These systems are likely to go through functional changes with ageing, given that older adults showed a poorer performance than young adults in all assessments. The differences found between the groups are consistent with the findings of previous studies where older adults were found to have a diminished acuity and sensitivity to visual contrast[22,23], smaller tactile sensitivity[24,25] and proprioceptive differences[26-28], when compared to young adults. The results of motor system assessments also confirmed previous results, which indicated a smaller knee and ankle joint torque among older people, when compared to younger people[27,29-32]. Besides the differences in the capacity to produce joint torque, the older adults took longer to activate the muscles in order to recover the postural balance after the base of support had been moved, which had also been reported previously[21,33,34].

Although generally supported by the literature, the hypothesis of an inferior motor and sensory performance among older adults may be questioned due to the lack of control for the effects of diseases associated with ageing. For instance, it may be difficult to determine whether functional differences in the sensory and motor systems of older adults are due to the ageing process itself. In the present study, the strict inclusion criteria minimized the risk of having such interferences, so one can be confident that the sensory and motor changes observed were predominantly originated from the ageing process.

Several studies looked into the contribution of the sensory and motor systems for postural control in older adults[9-12]. Nevertheless, many divergences were found among these studies, which may have occurred due to the inclusion of older participants who had diseases associated with ageing. For example, Lord, Clark and Webster[12], who pioneered a more thorough assessment of the contribution of the different sensory inputs and of the motor system to postural control, verified that tactile sensitivity and proprioception of the lower limbs were the most important variables for the maintenance of the upright position on a hard surface. Some years later, Lord and Ward[11] used similar methods in another study and concluded that the variables tactile sensitivity, sensitivity to vibration, and force were the most important to keep stability in an upright position. More recently, Lord and Menz[10] found that only the reduction in proprioception of the lower limbs was significantly associated with an increase of body sway in an upright position. Despite these divergences, the studies conducted by Lord and Menz[10] and by Lord, Clark and Webster[12] indicated a significant contribution of the proprioceptive system, either in isolation or in conjunction with other systems, for the postural control of older adults. The importance of this system for the postural control was corroborated in the present study by the results of the multiple linear regression analysis. This analysis showed that more impaired proprioceptive systems predicted greater amounts of body sway. This result indicates a significant and important contribution, not to mention preponderant, of the proprioceptive information for the performance of postural control, at least under the conditions evaluated in the present study.

Nevertheless, the relationship between the somatosensory information and the body sway while in upright position must be interpreted cautiously. Firstly, the use of sensory information for postural control depends on the context where the task is being carried out[8,35]. Secondly, the predominance of a certain sensory input over the others may be related to the deterioration of the remaining sensory inputs[36]. In the case of older adults, the somatosensory system would play a more incisive role, since the sensory vestibular and visual inputs, altered by the natural ageing process, would not provide sensory information with enough quality to guarantee a more precise control in the upright position. Despite this finding, the aspects related to the functional changes of the sensory systems and their respective contributions for postural control are only beginning to be investigated[37] and other studies need to be carried out so that these phenomena can be better understood.

Although neglected, studies carried out in the last decades point towards an intricate relationship between sensory information and motor activity, corresponding to the functioning of postural control. Thus, not only motor changes (for example, muscle strength[9,11]) should be considered in understanding the functioning of the postural control system or the changes in its functioning due to ageing, but also changes in sensory input and the interaction between this input and the central nervous system. This interaction allows the identification of the forces acting on the body and the changes in postural orientation originating from them, leading to the planning of proper motor responses.

This study showed that the sensory and motor changes probably occur due to the ageing process, and when it comes to maintaining an upright position, the reduction in the perception of joint movement appears to be the main component that affects postural control among older adults. This finding calls for a greater attention towards future studies on older people's postural control, particularly investigating possible interventions that might reduce the deterioration of the somatosensory information, resulting in a better control of the upright position.

One of the limitations of the present study was that, similarly to previous studies[11,12,19], the assessment of proprioception was not purely sensory as it consisted of a motor-sensory evaluation of motor response to the perception of joint movement. This challenges conclusions of sensory deterioration, since the delay in the response may be due to afferent, as well as to efferent pathways. The afferent and efferent involvement in the proprioceptive assessment must be investigated into detail so that a more precise statement can be made in relation to the motor and sensory contributions for postural control.

Finally, it is expected that the results of the present study will stimulate future studies on the relationship between changes in postural control among older adults and the great incidence of falls in this population. It is also expected that further investigations on this topic will be beneficial to healthcare services by assisting the prevention of falls among older adults.

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