Effects of aging and base of support in postural control

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Abstract

This study aimed to evaluate the postural control of young and elderly in relation to the predominant direction and the body sway area of the center of pressure, in order to verify whether different bases of support could evidence differences between groups for the two variables. The sample was composed of eight young adults (22.6 ± 2.33 years) and eight elderly (75.4 ± 5.7 years), and the task consisted of upright stance on a force plate for 30 seconds at two support bases: normal (BSN) and semi-tandem (BSST), being carried out three trials each. We evaluated the variables area and direction of sway, both derived from the center of pressure. Results showed that elderly presented higher body sway than young adults, and constraints in bases of support amplify body sway of both groups. We conclude that young and elderly present different behavior in relation to body sway and the increase in the task difficulty is able to partially highlight these differences

KEYWORDS: Postural control; Aging; Basis of support; Quiet stance.

Introduction

It is a hard task to maintain postural control. It requires interaction between many systems, has as its function maintain the center of gravity within the boundaries of the basis of support[1], as means to control and stabilize a multi-segment systems with many degrees-of-freedom[2]. In postural control, as in other actions in motor behavior, many components interact resulting in given muscle-pattern activities[3], in which there is a dynamic interaction involving muscles, sensory and the nervous system[4].

Postural control can be evaluated by means of the center of pressure (COP) measure arising from the postural sway in quiet standing. From this, one can derive several variables such as the area (i.e., the ellipse encompassing 95% of the COP trajectory), and the angle (θ) between the ellipse main axis and antero-posterior axis - which indicates the main direction of postural sway[5-6].

An interfering factor of postural sway is the basis of support which can alter the requirements on the involved systems of postural sway evidencing differences in the strategies used by distinct age groups in postural control[7-8]. Still, in aging, the usage of strategies in posture might change provided that aging results in functional and motor loss. This can reflect not only on the form, but also the variability in behavior observed in these individuals[6,9-10].

Thus, the current paper investigated whether changes in the basis of support would increase task difficulty in a way that can differentiate young and old adults in terms of main direction of oscillation and area of postural sway. This study aims to analyze the postural sway considering a) the age effect (young versus old adults), as well as b) the effect of basis of support.

The first hypothesis is that old adults will show larger postural sway than young adults, measured by COP, once that changes in organism would lead to modifications in the ability to maintain stability. The second hypothesis is that a smaller basis of support would amplify the differences between groups, in terms of area and main direction of body oscillation (COP motion). Such hypothesis is justified in that, in a more demanding basis of support, the old adult behavior would deteriorate to a larger degree than the young adult.

Methods

Sample

Eight young (M=22.6; DP=2.33 years; five females) and eight old adults (M=22.6; DP=5.7 years; seven females), all healthy, right-handed, non-institutionalized, agreed to participate and signed the informed consent form. The research was approved by the Institutional Review Board from Federal University of Minas Gerais (protocol: 01258012.6.0000.5149). The exclusion criteria were lower limb amputation; hip or knee prosthesis placement; diabetes; previous brain stroke; Parkinson disease; any neuromuscular, muscular injury, or visual limitation that would compromise the task performance; being in need of walking stick to maintain posture; or having vertigo.

Task and Apparatus

It was performed static posturography in force platform (EMGSystem - BIOMEC 400; signal conditioner - model CS 800 AF), with area of 50.0 x 50.0 cm and sampling rate of 100 Hz[11]. All scripts were implemented in Matlab 7.0. The data signal was filtered with a low-pass filter of 10 Hz.

During the task, the individual was barefoot, in a straight posture, looking at a point (black sphere with 5 cm diameter) fixated in a white wall 2 meters away at the eye-height. Each participant performed the task under two bases of support conditions. In the normal base of support (BSN), the feet stayed side-by-side being separated up to the hip length with the individual choosing the most comfortable distance. In the semi-tandem base of support (BSST) consisted in positioning the feet one in front of the other with the left foot heel at the same level of the top of the fifth metatarsophalangeal joint of the right feet[12]. In each trial, the participant stayed in orthostatic position for 35 seconds, with the feet always maintaining contact with the platform. For each condition, the participant performed three trials which resulted in six time-series with 35 seconds for each individual (three for BSN and three for BSST).

Procedures

The data collection was performed in a single day in a quiet place. After understanding the procedures and signing the consent form, the participant went to the data collection room and heard the task instructions. During data collection, the participants were instructed to not talk and to avoid motion as much as possible.

Data analysis

The first five seconds of each time series were not considered. The three time-series of 30 seconds of a given individual, in a given condition, were divided in 10-second segments resulting in nine time series (for each individual in a given condition). Provided the dominant frequency of oscillation for COP lies between 1 to 2 Hz[8,12], the 10-second period was chosen given it allows observation of 5 to 10 oscillation cycles in each time series of 10 seconds.

The dependent variables of the current study – COP main direction and area – were obtained from the 10-second periods and the nine values of each subject were grouped. The COP area was calculated using the confidence ellipse – that encompass 95% of the COP motion. The main direction of sway (angle θ) was calculated by measuring the angle between the main axis of the confidence ellipse and the antero-posterior axis with a negative value representing the left side of the participant and a positive value representing the right side of the participant[5-6].

To compare area and angle θ between the age groups and between conditions we run a repeated-measures ANOVA with age groups as a between group variable (young and old adults) and conditions as a repeated measure (BSN and BSST). When necessary, we performed the Tukey's post hoc given that the data did not differ from a normal distribution (Shapiro-Wilk' Test) and showed homogeneous variance (Levene' Test). For data analysis, we used the STATISTICA 7.0 considering 0.05 the level of significance.

Results

TABLE 1 presents the mean and standard deviation of main direction of sway (angle θ) and area for young and old adults in both conditions (BSN and BSST).

TABLE 1 - Descriptive statistics of main direction of sway of COP and COP area for the 10-second intervals.

Group Base of Support	Sway Direction¥ (Mean ± SD)	Sway Direction¥ (minimum/maximum)	Area (mm^2) (Mean ± SD)
BSN			
Old	2.2 ± 17.53	-50/ +78	32.1 ± 18.4
Young	-1.0 ± 7.42	-24/ +16	30.7 ± 20.7
BSST			
Old	-53.5 ± 55.18	-89/ +89	296.0 ± 140.2
Young	25.7 ± 65.85	-90/ +90	241.4 ± 208.8

¥Sway direction in degrees;
SD: Standard deviation;
BSN: Normal base of support;
BSST: Semi-tandem base of support.

In the BSN, the sway amplitude in the main COP sway direction was larger for old than young adults. In the BSST, the sway amplitude was similar between groups. In comparing the mean direction of sway, we found significant main effects for groups F(1,142)=5.6110, p=0.019, conditions (base of support), F(1,142)=60.313, p=0.001, and an interaction effect between groups and conditions F(1,142)=8.9356, p=0.003 (FIGURE 1). The Tukey's post hoc analysis showed that the old adults have a larger mean direction of sway than young adults in BSST (p=0.001), but not in the BSN (p=0.973). Both groups showed larger sway direction in the BSST than in BSN (p<0.001).

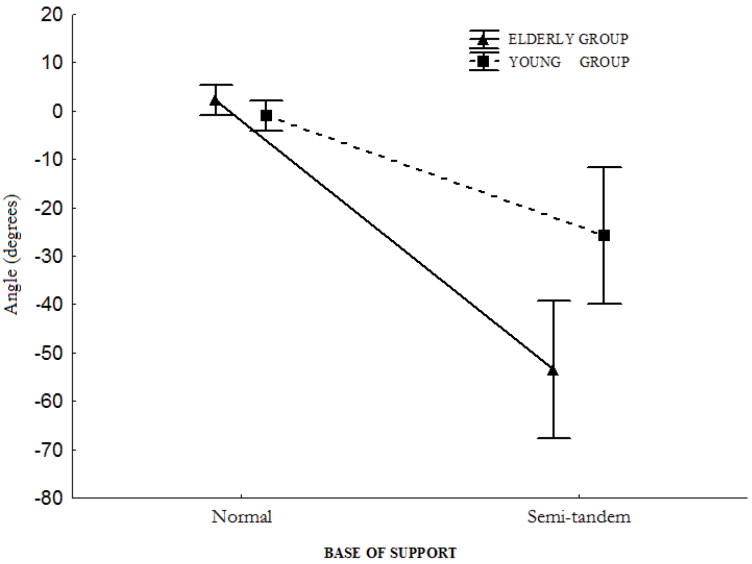

FIGURE 1 - Mean direction of sway (angle θ) in normal and semi-tandem basis of support for the elderly and young groups. The vertical bars indicate the 95% confidence interval.

In terms of area, we found significant main effects for groups, F(1,142)=11.760, p=0.001, with old adults showing a larger area of sway than young adults, and for conditions, F(1,142)=406.01, p=0.001, with larger sway area in BSST than BSN. There was also a significant interaction between groups and conditions, F(1,142)=12.490, p=0.001 (FIGURE 2); the Tukey's post hoc analysis showed that in both base of support, old adults showed larger COP area than young adults (p=0.001); also, old and yound adults swayed more in BSST than BSN (p<0.001).

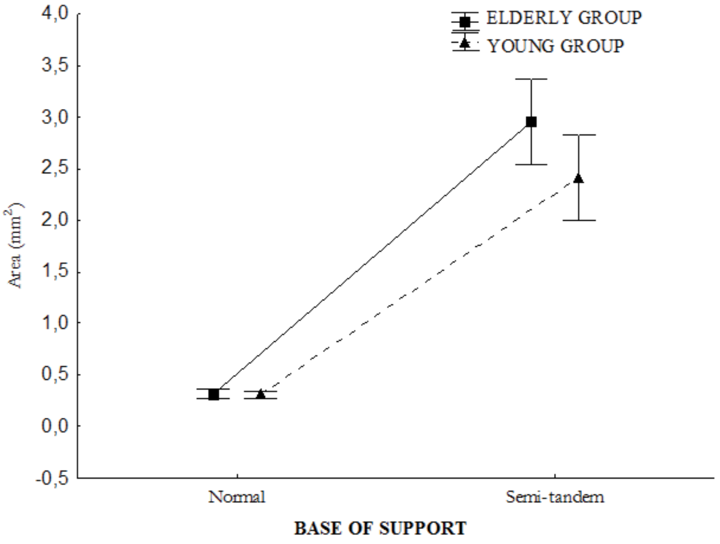

FIGURE 2 - Mean area (mm^2) in normal and semi-tandem basis of support for the elderly and young groups. The vertical bars indicate the 95% confidence interval.

Discussion

The first goal of the present study was to analyze the differences in body sway between young and old adults in quiet standing. The results showed larger sway for old adults which demonstrate the differences in the ability to maintain stability given the age group characteristics. The behavior in a task reflects a range of intrinsic constraints, including the aging effect on the system (individual), but also extrinsic constraints, related to the specific requisites to perform a task[13].

Mainly, in terms of COP area, old adults presented higher values than young adults in both BSST and BSN. While some studies that compared young and old adults in normal base of support[14-15] found differences between the COP area values, corroborating with the present work, other studies did not find such difference[7,16-17]. The larger area of postural sway might reflect the inefficacy in postural control and deficits in the fine adjustment of movements. This can be related to poor usage of somatosensory information for correction, reflecting delays and imprecision in the sensory feedback in detecting the position of the center of mass[5]. Notice that a larger sway area can result in the center of mass crossing the stability boundaries and, consequently, a fall. In this way, one can affirm that the second hypothesis of the present study was confirmed, provided that the implementation of a more restrict base of support (BSST) increased the differences between young and old adults only for the sway direction. Nevertheless, in terms of sway area, there was differences between groups in both conditions.

In considering the second goal of this work, when we compared the sway direction in both conditions (BSN and BSST), we did not observe significant differences between groups in BSN, different than BSST – in which all old adults tended to show sway to the left of the antero-posterior direction and young adults to the right. In BSN, young and old adults showed sway around the antero-posterior axis, as observed in Rocchi et al.[5], which possibly relates to the feet position adopted that provides an increase in support in the mediolateral axis, favoring an antero-posterior sway. Nevertheless, old adults increased the sway amplitude in the main direction of sway when compared to young adults, which can be associated with a higher activity of the abductor and adductor muscles of the hip – that control the load/unload mechanism – in relation to the dorsiflexors and plantar flexors[18], indicating a higher mediolateral stability in this group. In fact, some studies associated the lateral stability control and increased lateral sway to the risk of falling in elderly[19]. In this sense, Winter et al.[20] called the attention for the importance of loss of balance in the mediolateral direction provided that this would be particularly hard to overcome. In this situation, the unload of the limb occurs in the opposite side of the falling direction, while in the antero-posterior direction a step forward/backwards (the step strategy) can be employed to avoid falling.

Depending on the base of support, several mechanism combinations (behavioral responses) of the ankle and load-unload of hip to maintain stability in quiet standing can occur, and this can be an explanation for the differences observed in the present work[20-21]. While BSN provides an increase in support in the mediolateral direction, BSST constrains the movement in this axis favoring an increase in sway in the direction of constraint – provided that the distance between feet is directly related to the body stability[8-9,22]. All participants, from both groups, reported that they were right-handed and performed the BSST condition with the dominant food (right) in front. However, while the main direction of sway of young adults concentrated on the right side of the antero-posterior axis of the body, in the direction of the foot positioned in front, old adults concentrated the sway direction to the left, where there was no base of support, probably due to the lack of ability to deal with high demanding situations.

In intermediary positions between normal and tandem (such as semi-tandem), both hip and ankle mechanisms are involved in postural control[23]. In the antero-posterior direction there is a partial cancellation between both, while in the mediolateral direction they reinforce (partially) each other, with a dominant effect of hip and a partial support from inversion and eversion muscles of the ankle[9,20,23]. In this way, we can infer that old adults in the BSST condition showed higher activity of the load/unload mechanisms of the hip (or even inversor/eversor muscles of the ankle) to stabilize posture which resulted in a higher mediolateral oscillation. Changes in the base of support – such as reduction of it – might require larger moment arms to guarantee the adequate restorative torque to correct center of mass position resulting changes in postural sway. If the employed torque is not ideal for the situation, the body might oscillate beyond the stability boundaries leading to a new correction requirement that reflects in COP parameters[8]. For this reason, individuals that lost some of the postural control systems (such as in aging) present more difficulty in maintaining postural balance. Aging is associated to loss of physiological function; and because of that, elderly adults have less ability to generate relevant muscle force and/or precision in performing a motor task; in a way that they do not attend to the demands with the same stability level[13].

In this way, the second hypothesis was corroborated because the increase in task difficulty resulted in differences, in terms of the COP area, provided that both groups were affected by the constraints in the base of support. Both young and old adults showed larger area in the BSST in comparison to BSN (FIGURE 2), corroborating with Barela et al.[7], which can be explained by the increase in task difficulty that can influence the COP derived variables. Thus, it is possible to argue that both groups were affected by the spatial constrain of base of support[22], with larger effects in old adults.

We conclude that old adults present body sway similar to young adults when performing a simpler task, common to the daily life. Nevertheless, when exposed to a task that challenges the postural control, older individuals show a more rigid behavior. Furthermore, in the harder task, old adults showed different sway direction and larger area. We speculate that this is associated to the use of different strategies to maintain postural stability compared to young individuals. The results of the present study suggest that the increase in task difficulty can expose the differences between different age groups.

Resumo

Efeitos do envelhecimento e da base de suporte no controle postural

Este estudo teve como objetivos avaliar o controle postural de jovens e idosos em relação à direção predominante e à área de deslocamento do centro de pressão, buscando verificar se diferentes bases de suporte evidenciam diferenças entre os grupos para estas duas variáveis. A amostra foi composta por oito adultos jovens (22,6±2,33 anos) e oito idosos (75,4±5,7 anos), e a tarefa consistiu em permanecer de pé sobre uma plataforma de força por 30 segundos, em duas bases de suporte: normal (BSN) e semi-tandem (BSST), sendo realizadas três tentativas em cada uma delas. Avaliou-se as variáveis "área" e "direção" de oscilação, ambas derivadas no centro de pressão. Os resultados mostraram que idosos apresentaram maior oscilação corporal que jovens e a restrição na base de suporte ampliou a oscilação de ambos os grupos etários. Conclui-se que idosos e jovens apresentam comportamentos distintos em relação à oscilação corporal e que o aumento na dificuldade da tarefa é capaz de evidenciar parcialmente essas diferenças.

PALAVRAS-CHAVE: Controle postural; Envelhecimento; Demanda da tarefa; Postura quieta.

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