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Age-related changes in human postural control of prolonged standing

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Abstract

The aim of this study was to characterize prolonged standing and its effect on postural control in elderly individuals in comparison to adults. It is unknown how elderly individuals behave during prolonged standing and how demanding such a task is for them. We recorded the center of pressure (COP) position of 14 elderly subjects and 14 adults while they performed prolonged standing (30 min) and quiet stance tasks (60 s) on a force plate. The number and amplitude of the COP patterns, the root mean square (RMS), speed, and frequency of the COP sway were analyzed. The elderly subjects were able to stand for prolonged periods but they produced postural changes of lesser amplitude and a decreased sway during the prolonged standing task. Both the adults and the elderly subjects were influenced by the prolonged standing task, as demonstrated by their increased COP RMS and COP speed in the quiet standing trial after the prolonged standing task, in comparison to the trial before. We suggest that the lack of mobility in elderly subjects may be responsible for the observed sub-optimal postural changes in this group. The inability of elderly individuals to generate similar responses to adults during prolonged standing may contribute to the increased risk of falls in the older population.

Keywords: Balance; Center of pressure; Posturography; Natural standing; Postural changes; Mobility

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1. Introduction

In our everyday life, we frequently stand for a prolonged period (more than a few minutes) while chatting to somebody, waiting in a line, or standing in a work environment, i.e., we stand in order to perform another task — which in this context may be referred as a supra-postural task [1]. In such natural standing, continuous low-amplitude and slow swaying of the body is commonly interrupted by postural changes characterized by fast and gross body movements [2–4]. These postural changes are thought to be performed in order to diminish the discomfort caused by psychological factors (increase of tension, mental stress, and reduction of motivation and concentration) and physiological factors (increase of venous pooling in the lower extremities, occlusion of blood flow, vertigo, muscular fatigue and increased joint pressure) [3–8].

Analyses of healthy adults standing for a prolonged period have quantified the average number of these postural changes, which are between 1 and 2 min^{-1} [3,6,9]. Such analyses have shown that, superimposed on these deterministic local events, humans present similar patterns of oscillation over different space and time scales, constituting a fractal stochastic process [10,11]. In this way, postural changes and an increase in body sway during prolonged standing are viewed as effective responses of the postural control system to complete the task with minimal effort. Nevertheless, standing for a prolonged period, i.e., for hours, causes fatigue [12,13,9]. Discomfort and fatigue related to prolonged standing have been estimated by scales of rated perceived exertion and discomfort, measurements of performance, electromyographic activity of leg muscles, venous pressure, skin temperature, changes in foot and leg dimensions and frequency of postural changes, among other variables [6,8,12–14,9]. The rationale for using frequency of postural changes as an indicator of fatigue during prolonged standing is that postural changes are viewed as a response to avoid discomfort and fatigue. Hence, it is expected that

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postural changes be performed more often across time due to the increase in discomfort and fatigue during prolonged standing.

All studies to date examining prolonged standing have evaluated healthy adult individuals, mainly because prolonged standing is common in working environments and frequently causes impairments in the workforce [12,4,9]. Despite the greater impact that prolonged standing may have upon individuals with balance problems, the effects of standing for a prolonged period on individuals other than healthy adults is unknown. An anecdotal recommendation suggests that elderly individuals should not stand for prolonged periods, although no study has focused on this issue. The basis for this recommendation lies with the fact that ageing is associated with decreases in many physiological functions related to postural control [15,16]. That elderly individual may be affected by balance problems and a lack of mobility is shown by the fact that 30% of individuals older than 65 years old experience falls. Falls are the leading cause of unintentional injury deaths for these individuals in the United States [17–19]. While falling is a multifactorial problem, it is possible that individuals with postural deficits, particularly elderly individuals, may be incapable of generating adequate postural responses during prolonged standing. This might lead to fatigue and ultimately contribute to the risk of falling.

Due to the decrease in the physiological functions related to ageing, elderly individuals may be more affected during standing tasks. Considering postural changes as responses to avoid discomfort and fatigue, it is possible that elderly individuals present a higher frequency of postural changes during prolonged standing. Conversely, elderly individuals are also affected by a decrease in mobility [20,21]. A lack of mobility may mean that elderly individuals present fewer postural changes or postural changes with decreased amplitude. A decrease in the number and amplitude of postural changes in elderly individuals could also reflect a strategy to voluntarily perturb the body to sway as little as possible due to fear of falling. The effect of fatigue on the postural sway during quiet standing of healthy adults has also received attention [22–24]. In these studies, fatigue has been induced by voluntary contractions of leg muscles in different motor activities. Increased postural sway during quiet stance after fatiguing exercise demonstrated that fatigue can cause deterioration of postural control in quiet standing. However, it is unknown how fatigue due to prolonged standing might affect the postural sway of elderly individuals during quiet standing.

In the present study, we address the manner in which elderly individuals stand for a prolonged period and how demanding this task is for them in comparison to healthy adults. We therefore carried out posturographic analyses of prolonged standing and quiet standing tasks performed by both groups of individuals. We hypothesize that elderly individuals will present a different behavior than adults during prolonged standing, and that their control of equilibrium will be more affected by this task.

2. Methods

2.1. Subjects

Fourteen elderly individuals with the following characteristics were included in the current study: mean age (±S.D.) of 68 ± 4 years, range 61–76 years, height of 1.58 ± 0.08 m, and mass of 64 ± 12 kg. Fourteen healthy adults (28 ± 7 years, range 19–40 years, 1.65 ± 0.11 m, and weighing 63 ± 10 kg) also participated in this study. None of the subjects in the adult group had any known history of postural or skeletal disorders, but in the elderly group there were three subjects with arthritis of the knee and two subjects with labyrinthitis. However, none of these problems were severe, and none of the subjects reported any particular problem in balance control, nor had a history of falling. In addition, there was no difference in the outcomes reported here among elderly subjects. All elderly subjects were enrolled in a physical activity program in our University for at least 1 year, which consisted of moderate physical activities twice a week. All subjects participated voluntarily and signed a consent form as required by the local ethics committee of the University of São Paulo.

2.2. Task

The subjects performed two tasks: one trial of prolonged standing for 30 min and two trials of quiet standing for 60 s (immediately before and after the prolonged standing). All trials were performed with the subjects barefoot on a force plate (AMTI, OR6-WP, 50.8 cm × 46.4 cm). In the quiet standing task, subjects were asked to select a comfortable position with the feet approximately at shoulder width and to stay as still as possible looking straight at a point about 2 m ahead at head height. In the prolonged standing task, subjects were allowed to change their posture freely at any time; there were no specific instructions on how to stand, except the requirement not to step off the force plate. During the daily living activities, a task such as prolonged standing is typically performed as a secondary one while something else is being done. To reproduce this aspect in laboratory settings, we have, in previous studies, asked subjects to talk to somebody else while standing for a prolonged period [3,6]. For better experimental control in the present study, all the subjects watched a television documentary about the Sao Paulo city. The TV set was located 2 m in front of the subject.

The forces and moments measured by the force plate were recorded at a 20-Hz sampling frequency and the center of pressure (COP) for the anterior–posterior (AP) and medio-lateral (ML) directions were calculated and analyzed.

2.3. Data analysis

Before analysis, the COP data were low-pass filtered with a Butterworth filter of fourth-order and an 8 Hz cutoff frequency. To remove the offset of the COP data, the mean was subtracted from each time series. Two types of analyses were performed on the COP data: a structural analysis to determine the postural changes during prolonged standing, and a standard global analysis in time and frequency domains to determine the root mean square (RMS), the mean speed, and the frequency of the COP displacement. In addition to the analysis of the 30-min and the 60-s trials, we compared the first 10 min of the prolonged standing to the last 10 min, to determine possible variations across time.

The postural changes during prolonged standing were analyzed quantifying specific patterns in the COP data with the method proposed by Duarte and Zatsiorsky [6]. This method assumes that postural changes while standing are associated with specific patterns of COP displacement. These authors identified the following three patterns in the COP data: (a) *shifting:* a fast displacement of the average position of the COP from one region to another (step-like); (b) *fidgeting:* a fast and large displacement followed by a return of the COP to approximately the same position (pulse-like); (c) *drifting:* a slow continuous displacement of the average position of the COP (ramp-like) [3,6]. Fig. 1 shows a representative example of the three COP patterns in a stabilogram (the COP time series) of the present study. Computer algorithms based on moving windows analysis and criteria such as amplitude and width thresholds for each pattern were developed to recognize these patterns. The amplitude threshold is established in comparison to the dispersion (measured by the standard deviation, S.D.) of the surrounding data, rather than absolute values of amplitude. A complete description of the algorithms is given elsewhere [3,6]. These algorithms and other parameter evaluations were implemented in the Matlab 5.1 software (MathWorks, Inc.) with a graphical user interface. The codes are available from the authors upon request.

The following criterion values were chosen for classifying the data as shift, fidget or drift patterns, respectively: a minimum shift amplitude of 2 S.D., a maximum shift width of 5 s and a base window of 15 s; a minimum fidget amplitude of 3 S.D., a maximum fidget width of 4 s and a base window of 60 s; a minimum drift amplitude of 1 S.D., a minimum drift width of 60 s. These values are similar to the values used previously in the literature [3,6]. A sensitivity analysis of the pattern identification to the choice of different parameters has been performed before [6]. Basically, with higher thresholds, the technique would be systematically less sensitive to postural changes.

In each direction, the mean speed (COP speed) was calculated by dividing the total COP displacement by the total period. The frequency of the COP displacement in each direction (COP frequency) was determined by the frequency at which 80% of the COP spectral power is below. The 80% value was chosen based on the work of Baratto et al. [25], who have suggested that this value is a superior discriminator for the COP data than other spectral measurements. The power spectral density was estimated by the Welch periodogram of the detrended data with a resolution of 0.039 Hz. The COP RMS, COP speed, and COP frequency variables were used to analyze the COP data from both the quiet standing and the prolonged standing trials.

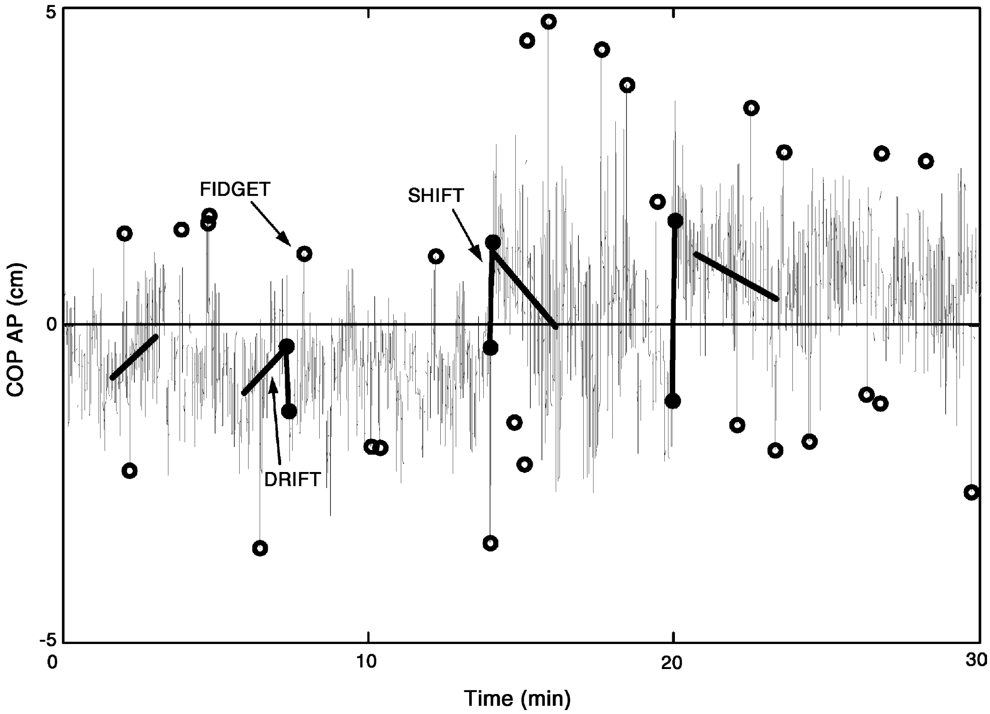

Fig. 1. COP patterns during prolonged standing (30 min): shifts (filled circles joined with lines), fidgets (open circles) and drifts (lines). The data represent COP displacements for the anterior–posterior (AP) direction of one adult.

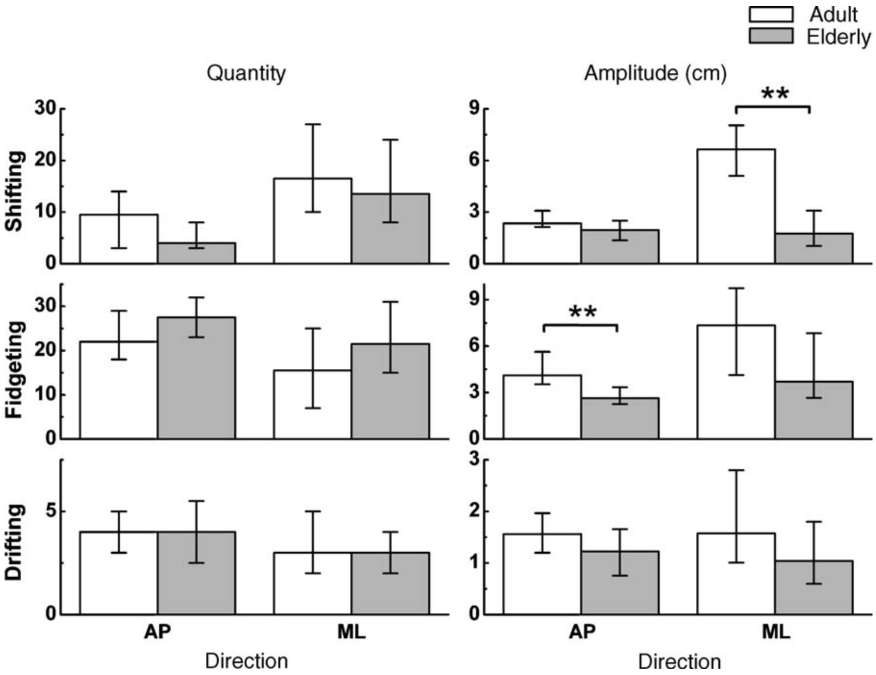

Fig. 2. Median and inter-quartile range values across subjects for adults and elderly individuals of the numbers and amplitudes of the shifting, fidgeting and drifting COP patterns in the anterior–posterior (AP) and medial–lateral (ML) directions during the prolonged standing trial (30 min). $^{**}P < 0.005$.

Nonparametric statistics were used to analyze the COP-pattern data due to the non-normality and non-homogeneity of variances (tested by the Shapiro-Wilk test and the Levene statistic, respectively). Mann–Whitney tests were used to investigate the effect of the group (adult versus elderly) on the COP patterns dependent variables (prolonged standing). Within each group, Wilcoxon signed ranks tests were employed to investigate the effect of prolonged standing on the dependent variables COP patterns of the first and last 10 min of the prolonged standing trial. The results of these tests are reported as *Z*-values. The COP-pattern data are summarized as median values, with 25th and 75th percentiles. Independent *t*-tests were used to investigate the effect of the group (adult versus elderly) on the COP RMS-, COP speed-, and COP frequency-dependent variables. Within each group, paired *t*-tests were employed to investigate the effect of prolonged standing on the COP RMS-, COP speed-, and COP frequency-dependent variables of the quiet standing trials before and after the prolonged standing trial and for the first and last 10 min of prolonged standing. The data for the COP RMS, COP speed, and COP frequency variables are summarized as mean and standard deviation. An alpha level of 0.05 was used for all statistical tests, which were performed in the SPSS 10.0 software (SPSS, Inc.).

3. Results

All the adults as well as all the elderly subjects were able to stand for 30 min and performed postural changes while standing. The median and inter-quartile range values of the amplitude and number of COP patterns in the AP and ML directions for the adult and elderly groups during the prolonged standing trial are shown in Fig. 2. The total number of COP patterns in the stabilograms was not different between adults (median, 25th–75th percentiles: 65, 57–76; 2.2 postural changes per minute) and elderly individuals (median, 25th–75th percentiles: 73, 57–90; 2.4 postural changes per minute), ($Z(26) = -0.34$, $P = 0.73$). Fig. 2 shows that the most frequent COP pattern was fidgeting for both groups. In number, fidgeting was followed by shifting and drifting. These patterns were approximately twice and six times less frequent than fidgeting, respectively. The numbers of each COP pattern for any direction measured were not different between adults and elderly individuals. However, both the amplitudes of shifts in the ML direction and fidgets in the AP direction were greater for the adult group in comparison to the elderly group (ML shifts: $Z(26) = -3.7$, $P < 0.001$; AP fidgets: $Z(26) = -2.89$, $P = 0.003$). The amplitudes of the ML shifts and of the AP fidgets were not correlated with subjects' stature, either between or within groups (all correlation coefficients < 0.5 and all *P*-values > 0.15). Although the adult group was on average 7 cm taller than the group of elderly individuals, this difference was not significant (independent *t*-test, $t(26) = 1.86$, $P = 0.08$).

The median and inter-quartile range values of the amplitude and number of COP patterns in the AP and ML directions for the adult and elderly groups during the first and the last 10 min of the prolonged standing trial are shown in Fig. 3. The numbers of each COP pattern for both directions were also undifferentiated between adults and

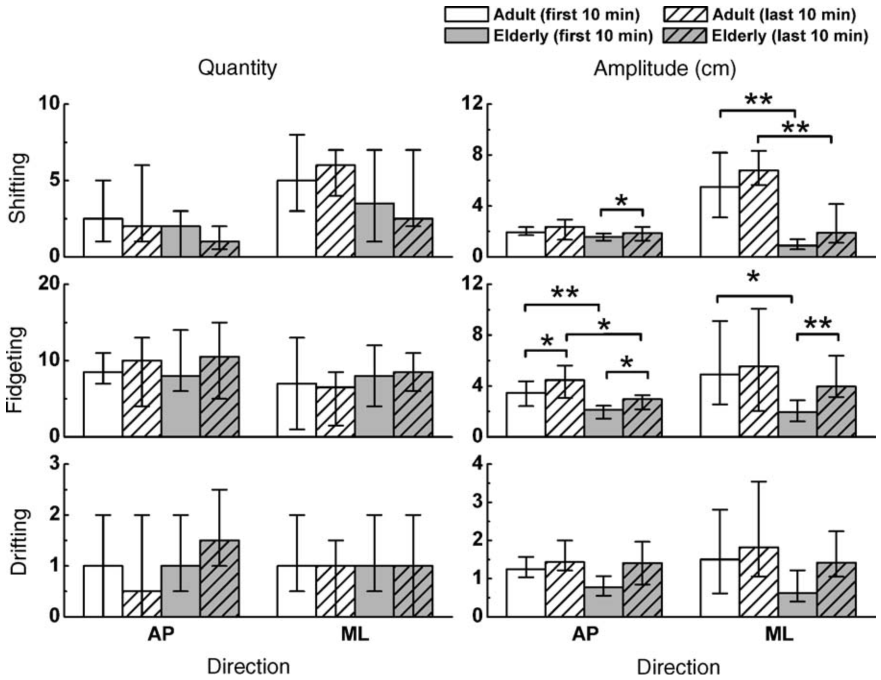

Fig. 3. Median and inter-quartile range values across subjects for adults and elderly individuals of the numbers and amplitudes of the shifting, fidgeting and drifting COP patterns in the anterior–posterior (AP) and medial–lateral (ML) directions during the first and the last 10 min of the prolonged standing trial (30 min). $^{*}P < 0.05$; $^{**}P < 0.005$.

elderly individuals. However, again both the amplitude of shifts in the ML direction and fidgets in the AP direction were greater for the adult group than for the elderly group during the first 10 min (ML shifts: $Z(22) = -2.89$, $P = 0.003$; AP fidgets: $Z(26) = -2.89$, $P = 0.003$), as well as during the last 10 min (ML shifts: $Z(24) = -3.0$, $P = 0.002$; AP fidgets: $Z(26) = -2.53$, $P = 0.01$). In addition, the amplitude of fidgets in the ML direction was greater for the adult group than for the elderly group during the first 10 min ($Z(24) = -2.50$, $P = 0.01$). Comparing the first 10 min to the last 10 min of the prolonged standing, again we observed differences only for the amplitude of the COP patterns. The amplitude of fidgets in the AP direction was greater in the last 10 min than in the first 10 min for the adult group ($Z(26) = -2.35$, $P = 0.02$), as well as for the elderly group ($Z(26) = -2.67$, $P = 0.008$). The amplitude of shifts in the AP direction and the amplitude of fidgets in the ML direction were greater in the last 10 min than in the first 10 min only for the elderly group ($Z(22) = -2.10$, $P = 0.04$; $Z(24) = -2.98$, $P = 0.003$, respectively).

The adults and the elderly subjects produced different patterns of COP sway during prolonged standing, as shown by the representative statokinesigrams (the map of COP AP versus COP ML) in Fig. 4. All adults displaced the mean COP location several times, showing a multi-center pattern in their statokinesigram. In comparison, 11 out of 14 elderly subjects presented only one center of mean COP location (one normal elderly, one with arthritis, and another with labyrinthitis presented a multi-center pattern). The number of COP centers in each statokinesigram was counted by visual inspection. Five different evaluators counted the number of COP centers for each participant, in order to verify the consistency between raters. Inter-rater reliability was measured by the intra-class correlation coefficient (ICC). The ICC result ($\mathrm{ICC}(2, 5) = 0.95$) indicated a strong degree of consistency between raters. On average, the adults showed six COP centers, while the elderly subjects showed only one COP center, a significant difference ($Z(20) = -4.3$, $P < 0.001$).

The mean and standard deviation values of the COP RMS, COP speed, and COP frequency variables in the AP and ML directions for the adult and elderly groups during the 30-min prolonged standing trial are shown in Fig. 5A. Fig. 5B shows the same variables for the first and last 10 min of the trial. For the entire trial, the COP RMS of the elderly group was smaller than the COP RMS of the adult group in both directions (AP: $t(26) = 2.38$, $P = 0.03$; ML: $t(26) = 4.04$, $P = 0.001$). For both the first and the last 10 min of the prolonged standing, the COP RMS of the elderly group was also smaller than the COP RMS of the adult group in the AP direction (first 10 min: $t(26) = 2.21$, $P = 0.04$; last 10 min: $t(26) = 2.25$, $P = 0.04$), as well as in the ML direction (first 10 min: $t(26) = 3.25$, $P = 0.004$; last 10 min: $t(26) = 3.25$, $P = 0.004$). Comparing the first 10 min to the last 10 min of the prolonged standing, the COP speed was greater during the last 10 min than the first 10 min for both the adult and the elderly groups and for both AP and ML directions (AP, adult: $t(13) = -4.35$, $P = 0.001$; elderly: $t(13) = -3.62$, $P = 0.003$; ML, adult: $t(13) = -3.55$, $P = 0.004$; elderly: $t(13) = -2.59$, $P = 0.02$). The COP

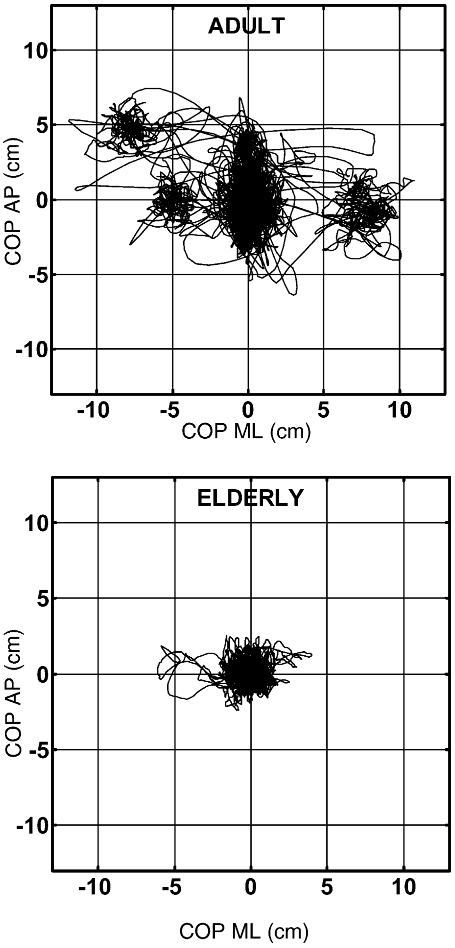

Fig. 4. Representative statokinesigrams for one adult and for one elderly individual during a prolonged standing trial (30 min).

frequency in the ML direction for the adult group was lower during the last 10 min ($t(13) = 2.72$, $P = 0.02$).

The mean and standard deviation values of the COP RMS, COP speed, and COP frequency variables in the AP and ML directions for the adult and elderly groups during the quiet standing trials are shown in Fig. 6. The COP RMS of the quiet standing trial after the prolonged standing was greater than during the trial before the prolonged standing for the adult group in the AP direction (43% greater, $t(13) = -3.09$, $P = 0.009$). In the ML direction, COP RMS was greater during the quiet standing trial after the prolonged standing than during the trial before for both adult and elderly groups (adult: 43% greater, $t(13) = -2.99$, $P = 0.01$; elderly: 46% greater, $t(13) = -4.19$, $P = 0.001$). The COP speed of the quiet standing trial after the prolonged standing was greater than during the trial before the prolonged standing for both adult and elderly groups in the AP direction (adult: 9% greater, $t(13) = -5.37$, $P < 0.001$; elderly: 11% greater, $t(13) = -2.38$, $P = 0.03$). In the ML direction, COP speed was higher during the quiet standing trial after the prolonged standing than during the trial before only for the elderly group (20% greater, $t(13) = -2.88$, $P = 0.01$). For both trials before and after the prolonged standing, the COP speed of the elderly group was greater than for the adult group in the AP direction (before: 48% greater, $t(13) = -3.58$, $P = 0.001$; after: 37% greater, $t(13) = -2.87$, $P = 0.008$), as well as in the ML direction (before: 38% greater, $t(13) = -2.12$, $P = 0.04$; after: 45% greater, $t(13) = -2.27$, $P = 0.03$). For the quiet standing trial before the prolonged standing, the COP frequency in the AP direction was greater for the elderly group than the adult group (47% greater, $t(13) = -2.77$, $P = 0.01$).

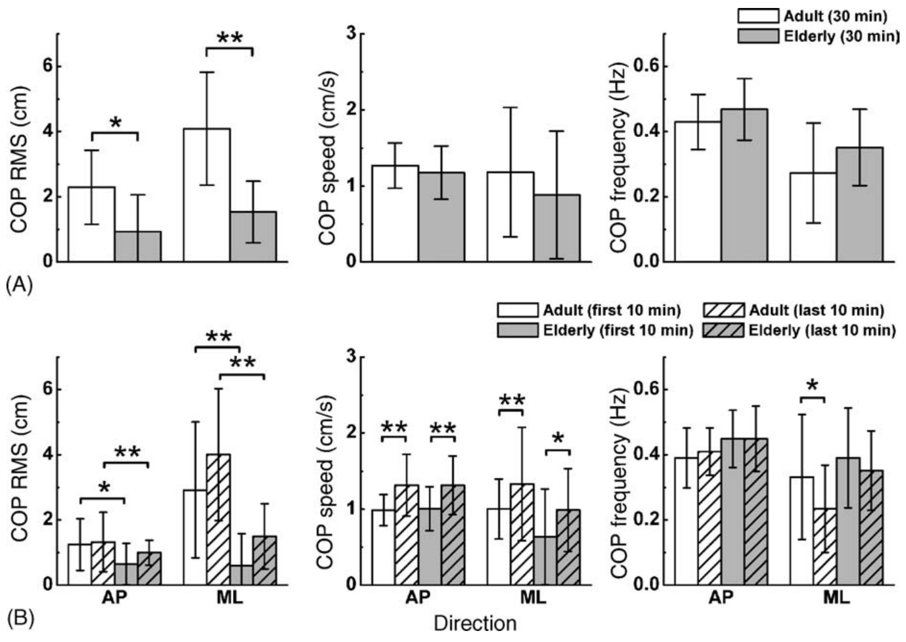

Fig. 5. Mean and standard deviation values across subjects for adults and elderly individuals of the root mean square (RMS), speed and frequency of the COP displacement during the 30 min of the prolonged standing trial (A) and during the first and the last 10 min of the trial (B). $^{*}P < 0.05$; $^{**}P < 0.005$.

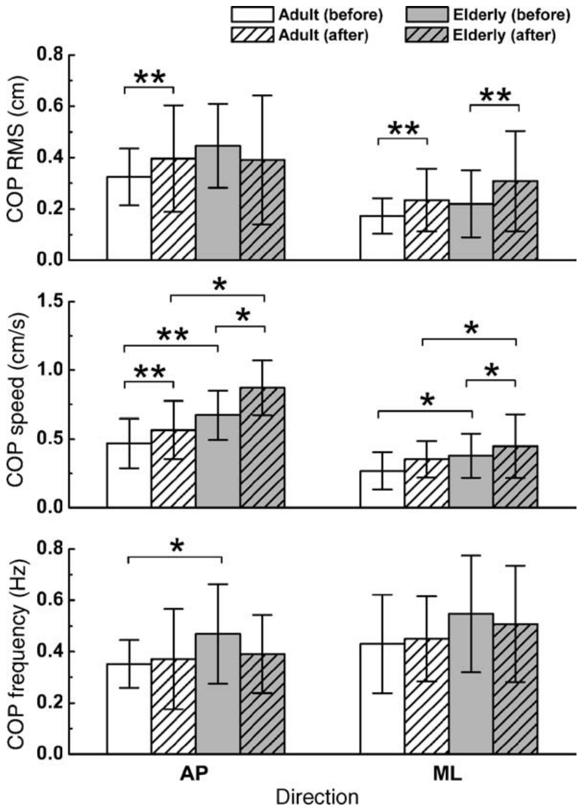

Fig. 6. Mean and standard deviation values across subjects for adults and elderly individuals of the root mean square (RMS), speed and frequency of the COP displacement during the quiet standing trials (60 s) before and after the prolonged standing trial. $^*P < 0.05$; $^{**}P < 0.005$.

A correlational analysis between the structural parameters and the global parameters of the prolonged unconstrained data for the adult group revealed that in the AP direction the number of fidgets was negatively correlated to COP RMS ($r = -0.70$, $P = 0.005$) and the amplitude of the fidgets was correlated to COP RMS ($r = 0.58$, $P = 0.03$). In the ML direction, the number of shifts and fidgets for the adult group was correlated to COP RMS ($r = 0.88$, $P < 0.001$; $r = 0.71$, $P = 0.005$, respectively) and the amplitude of shifts was correlated to COP RMS ($r = 0.83$, $P < 0.001$). For the elderly group, the amplitude of shifts and fidgets in the AP direction was correlated to the COP RMS ($r = 0.92$, $P < 0.001$; $r = 0.76$, $P = 0.002$, respectively) and correlated to the COP speed ($r = 0.70$, $P = 0.005$; $r = 0.62$, $P = 0.02$, respectively). In the ML direction, the amplitude of shifts and fidgets for the elderly group was correlated only to the COP RMS ($r = 0.68$, $P = 0.008$; $r = 0.88$, $P < 0.001$, respectively).

4. Discussion

The purpose of the present study was to characterize prolonged standing and its effect on postural control in elderly subjects in comparison to adults. We hypothesized that elderly individuals would present a different behavior to that in adults during prolonged standing. We also expected that postural control would be more affected by prolonged standing for the elderly subjects, in comparison to adults. Our main findings suggest that elderly individuals exhibit postural changes of smaller amplitude and lesser sway than adults during prolonged standing. Although our results also demonstrate that both groups are affected by the prolonged standing task, they do not clearly establish which of the two groups was more affected.

The average number and amplitude of the COP patterns for the adult individuals during prolonged standing are similar to the data reported in the literature for healthy adults [3,6,9], although there is substantial variability in these numbers between subjects. For the elderly subjects, the amplitude of shifts in the ML direction, the amplitude of fidgets in the AP direction, and the RMS of the sway were each smaller than those measured in the adult subjects. These results are consistent with the observation in the statokinesigrams of an average of only one COP center for the elderly group and six COP centers for the adult group. However, Duarte and Zatsiorsky [6] found only one COP center for the majority of the adults who performed the unconstrained standing task. We can attribute this difference to the different criteria used to count the COP centers and to the different experimental conditions, which include the different laboratory environments and the tasks the subjects performed (in Duarte and Zatsiorsky's study, the subject was permitted to communicate occasionally with another person; in the present experiment the subject watched TV). Nevertheless, the important point is that, under the same conditions, the adult and elderly groups presented an expressive difference between them.

Larger shift amplitude is responsible for generating different COP centers in the statokinesigram [6]. Shifts in the ML direction are typically a reflection of unloading–loading the body weight from one leg to the other. As early as 1913, Mosher stressed the importance of shifting the body weight from side to side for better comfort [26]. Our experimental setup with only one force plate could not determine whether the observed COP shifts were due to weight transfer from one leg to the other or whether they were due to a step movement aside, for example. The subjects were allowed to change their posture freely at any time throughout the experiment and there were no specific instructions on how to stand, except the requirement not to step off the force plate. However, a qualitative visual observation of the subjects during the prolonged standing task indicated that the COP shifts were indeed caused by the load–unload mechanism, and hence, that subjects did not move their feet so frequently.

With much lower amplitude, a load–unload strategy in the ML direction has also been identified as the main mechanism for postural control in the ML direction during quiet standing [27]. Differences in postural control between adults and elderly individuals during quiet standing have been found in the ML direction, and McClenaghan et al.

suggested that these differences during quiet standing may be related to the increased risk of falls associated with age [28]. Similarly, the reduced amplitude of the shifts in the ML direction by the elderly individuals found here also suggests a deficit in the load–unload mechanism of postural control during prolonged standing. This reduced amplitude of the shifts in the ML direction may also reflect a more cautious stance because of fear of falling. Although we did not investigate elderly individuals with history of falls, it is possible that this deficit is related to the risk of falls for elderly individuals.

We found that during prolonged standing the elderly subjects swayed less than adults in both AP and ML directions, as measured by the COP RMS variable; while during quiet standing there was no difference. Conversely, the elderly subjects showed greater speed of sway than the adults during quiet standing in both AP and ML directions; while during prolonged standing there was no difference. In fact, the nature of 'sway' in these two tasks is not the same. The large sway during prolonged standing is in fact due to postural changes, voluntary movements performed from time to time. This is supported by the observed correlations between the amplitude and number of postural changes with the COP RMS and COP speed during prolonged standing. In this sense, in addition to equilibrium maintenance, mobility also plays an important role in prolonged standing. Given the fact that elderly individuals present postural deficits as well as lack of mobility [20,21], prolonged standing of elderly individuals may be affected by alterations in either or both of these parameters. In the current study, the lack of mobility seemed to have a stronger effect on the elderly individuals, and consequently they moved less during the prolonged standing task. Lack of mobility has also been identified as a factor related to falls, in that a subject with a lack of mobility may not be able to respond with the appropriate intensity to an external perturbation that may cause a fall [20,21]. In addition, based on the present results, we suggest that the lack of mobility in elderly individuals may also be responsible for the observed sub-optimal postural changes (internal perturbation) necessary to stand for a prolonged period. This sub-optimal response may cause a failure of the postural control system to respond to an external perturbation while the individual is standing for a prolonged period. This may ultimately result in a fall.

According to the hypothesis that prolonged standing deteriorates postural control, we would expect an increase in postural sway during quiet standing after the prolonged standing task, and an increase in the frequency of COP patterns across time during the prolonged standing. The results partially confirmed these propositions for the adults and the elderly subjects: COP RMS and COP speed of quiet standing were greater after the prolonged standing task, and COP speed and the amplitude of the COP patterns (not the frequency) were greater in the last 10 min than in the first 10 min of prolonged standing. Although we do not have a direct measure of fatigue in the present study, given that it has been shown that standing for a prolonged period causes fatigue [12,13,9], we interpret the current results as an effect of fatigue. A deterioration of postural control during a quiet standing task has also been observed after fatiguing activities such as long-term running or cycling [23,29,24]. We hypothesized that the elderly subjects would be more affected by the prolonged standing. If increases in the measurements of sway during the quiet standing trial after the prolonged standing, in comparison to the trial before, are assumed to be indications of fatigue, the present results to not provide clear evidence as to which group of subjects was more affected. Nevertheless, these results support the anecdotal recommendation that elderly individuals should not stand for prolonged periods. Although we observed a deterioration of the postural control for both groups, this deterioration may have more serious consequences for elderly individuals, as they may already present postural deficits [15,16].

Although we found that elderly individuals produce postural changes of smaller amplitude and lesser sway during prolonged standing, one should be cautious in recommending someone to perform postural changes of larger amplitude during prolonged standing. It is necessary to understand the causes of these changes among elderly individuals in the context of postural control and mobility before any intervention is proposed.

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