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Postural Sway during Dual Tasks in Young and Elderly Adults

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Balance · Aging · Posturography

Abstract

Background: Previous studies have shown that healthy young adults are able to decrease their standing postural sway when an additional postural visual task, such as reading, is performed. ***Objective:*** In this study, we investigated postural sway during dual tasks in young and elderly adults. ***Methods:*** Twelve healthy active elderly adults (aged 65–75 years) and 12 healthy young adults (aged 22–39 years) participated in the study. The subjects performed different visual tasks while standing on a force plate. We varied the nature of the visual tasks (looking at a blank target versus a visual search task) and the distance of visual targets (near versus far). Center of pressure displacement obtained from the force plate data and kinematics of body segments obtained from a video analysis system were investigated. ***Results:*** Both groups presented significantly larger postural sway in the mediolateral direction during the eyes-closed condition as compared with the eyes-open condition. In the anteroposterior direction, this effect was observed only for the elderly group. Both groups had the same percentage correct in counting letters, but the elderly adults were significantly slower as compared with the young adults. The amplitude of postural sway was greater for the elderly adults than for the young adults in all conditions. However, both the young and the elderly adults exhibited significant reductions in sway during performance of the search task relative to sway during viewing of a blank target. The sway was also reduced for both groups during viewing a near target when compared to a distant target. ***Conclusions:*** The results suggest that, despite the overall increase in postural sway with aging, subtle integration of visual information by the postural control system is not affected by aging. The present results support the idea that dual tasks do not necessarily lead to an increase in postural sway. This effect, found here in elderly adults, raises questions about widely held views in which age-related changes in postural sway are related to competition between postural control and other activities for central processing resources.

Introduction

Control of the balance in upright standing is not an automatic task mediated entirely by reflexes. Instead, it depends on a complex and active control system. Older adults tend to sway more and rely more on visual information to maintain balance, as revealed by laboratory studies employing quiet (unperturbed) and dynamic (perturbed) posturography [1–3]. Such age-related changes have been interpreted as degradation in postural control and have been attributed to decreases in sensory or motor system functions or in cognitive tasks [3, 4].

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One form of investigating the role of cognitive demands in postural control has been the dual-task paradigm, in which subjects attempt to execute a nonpostural task during stance. The dual-task paradigm is especially relevant, because it can be argued that we are always doing something else while standing. The use of the dual-task paradigm has been inspired, in part, by the position that the control of stance competes with other activities (e.g., reading) for a central pool of processing resources. Furthermore, in dual-task situations, an increase in postural sway is expected, especially in subjects with possible postural deficits, such as elderly individuals. Indeed, several studies reported an increase in postural sway for young and older adults during dual tasks [5–9], compatible with the idea of competition for central resources.

Studies using a dual-task paradigm to examine the effects of age-related changes in cognitive demands on postural control have often reported that dual-task situations are associated with increased postural sway in both healthy and balance-impaired elderly individuals [4]. However, other studies performed in young adults have found no differences for some dual tasks [10, 11], while in some studies there have been reductions in sway during performance of cognitively demanding tasks [12–14], including one study done in older adults [15]. In this study, Melzer et al. [15] observed an increase in postural sway of younger and older adults when a cognitive task was performed during standing on a wide base of support. Interestingly, when the same subjects stood on a narrow base, the older group decreased their body sway, while the younger group increased it. With electromyography, these authors verified that the older adults decreased their body sway by coactivating their muscles around the ankle joint, 'probably because of the danger to their postural stability' when performing the cognitive task in the narrow-base condition.

After reviewing studies on postural control and central cognitive resources, Woollacott and Shumway-Cook [4] concluded that in ordinary stance by young adults, the effects of cognitive load on postural control appear to be small, but that these effects can be substantial in elderly individuals.

In daily life activities, the distance to a visual target and its content may vary during some dual tasks while standing; these influences on postural sway have been studied by Stoffregen et al. [14]. They have found that the amplitude of standing body sway was reduced when young adults looked at nearby targets (relative to sway during viewing of distant targets) and that sway was reduced during a demanding visual task (visual search of target letters in a text) relative to sway during a less demanding visual task (viewing a blank target). Stoffregen et al. [14] interpreted these results as an expression of a functional integration between postural control and the suprapostural task, i.e., the postural control system intentionally decreased the postural sway in order to facilitate the visual performance in the dual task [for a more detailed description see ref. 14]. An alternative view is that in such dual tasks, the postural control system is able to better use visual cues from the environment given by the text and nearby targets, possibly due to retinal slip or proprioceptive signal from extraocular muscles [16–18].

Stoffregen et al. [14] studied only healthy young adults, and it is unknown how older subjects behave during such dual tasks. Due to the age-related degradation in postural control, it is relevant to investigate whether elderly people would be affected in a similar way. With such an investigation, we sought to better understand the effect of aging on the integration of the visual information by the postural control system. Therefore, in the present study, we replicated and extended the study of Stoffregen et al. [14] to include older adults, comparing sway in young and elderly subjects. We attempted to replicate classical effects observed in postural research, including an increase in sway when the eyes were closed and an overall increase in sway among healthy elderly subjects (relative to young adults). Our primary hypothesis was that elderly subjects would exhibit the same behavior during such dual tasks that was observed in young adults.

Methods

Twenty-four volunteers took part in the study, 12 subjects for each age group. The young-group age ranged from 22 to 39 years; mean (± SD) weight 63 ± 8 kg and height 1.63 ± 0.06 m. The age of the elderly group ranged from 65 to 75 years, with weight 74 ± 15 kg and height 1.64 ± 0.10 m. The groups were significantly different with regard to age [$t(22) = -24.69$, $p < 0.001$] and body mass [$t(22) = 2.32$, $p = 0.03$]. No subject reported any history of neurological or musculoskeletal disease, dizziness, falls, or complaints of vertigo. The subjects had a normal vision, as evaluated by the Freiburg Visual Acuity test [19]. Both groups presented a similar visual acuity (young adults: 1.7 ± 0.4; elderly: 1.6 ± 0.3). The elderly subjects were enrolled in a physical activity program for at least 1 year which consisted of low-intensity physical activities twice a week. To take part in this group, they were submitted to a preview clinical evaluation. The study was approved by the local ethics committee of the University of São Paulo.

The subjects performed two types of tasks while standing: suprapostural visual tasks [14] and control tasks. The suprapostural tasks consisted of four conditions, where we covaried the type of visual task (inspection versus search) and the distance of the visual targets (near versus far). The control tasks were performed in order to understand how our subjects were affected by vision and consisted of two tasks: one with eyes open (EO) and one with eyes closed (EC).

In the inspection task, the subjects viewed a blank target (a piece of white paper) and were instructed only to keep their gaze within the borders of the target. In the search task, the subjects viewed a block of text (in Portuguese) and were instructed silently to count the number of appearances of a designated target letter and to report the total at the end of each trial (as well as their final position in the text). The subjects were told that if they finished reading the text before the end of the trial, they should start again at the beginning. The target letters were A, E, O, N, S, and R; a different letter was used for each trial. The number of target letters in a text block ranged from 44 to 97. The font size of the target letters was adjusted so that the visual angle of individual letters was the same for near and far targets. Near targets were positioned 0.4 m from the subject and consisted of a piece of paper, 17 × 13.5 cm. Far targets were positioned 3.0 m from the subject and consisted of a piece of poster board, 1.03 × 0.86 m. From the subject's position, the near and far targets had the same visual angle. The lower edge of the far target was positioned at the subject's eye height, as was the upper edge of the near target. Regarding the control tasks, during the EO condition, the subjects were instructed only to look to a wall 3 m ahead. For the suprapostural tasks, the subjects completed three trials in each condition and only one trial for each control task. The order of all trials was randomized across subjects. The duration of each trial was 70 s.

We measured the center of pressure (COP) displacement and the subject's body movements. These two types of measurements permitted us to compare the present results with those of previous studies [14, 18, 20] which have commonly used only one or the other of these measurements. The subjects stood on a force plate (OR6-WP-1000; AMTI, Watertown, Mass., USA) with the feet approximately 10 cm apart. We computed the COP displacement in the anteroposterior (AP) and mediolateral (ML) directions. The subject's body movement in the sagittal plane was registered using an infrared camera system (Proreflex 240; Qualisys, Göteborg, Sweden). Reflective markers were affixed to the right side of the subject's head, shoulder, hip, knee, ankle, and forefoot. All signals were acquired at 100 Hz.

Data Analysis

The visual performance was evaluated in terms of percent correct in the search task. Percent correct was calculated by dividing the total frequency of occurrences reported by the frequency of actual occurrences in the amount of text that was reported as being scanned.

The first and last 5 s of the data were removed after low-pass filtering at 10 Hz with a fourth-order and zero-lag Butterworth filter, since most of the power of the signal was <2 Hz [for a review see ref 21]. We computed the root mean square (RMS) and mean speed of COP displacements separately for the AP and ML axes. We defined the COP speed as the total COP displacement divided by the total period. For the kinematic data, we determined the linear displacements of head, shoulder, hip, and knee in the AP axis, defined as the difference between the maximal and the minimal position of each marker.

To determine which age group was more affected by manipulation of the factors of target and distance, we computed for each analyzed variable the ratio between the different conditions (distance factor: far inspection/near inspection and far search/near search; target factor: far inspection/far search and near inspection/near search).

Normality and homogeneity of variances of the data were confirmed by the Kolmogorov-Smirnov and the Lilliefors tests, respectively. Two-tailed independent t tests were used to determine the differences for the variables age, body mass, height, and visual acuity and the ratios listed above. For the control conditions, two-factor ANOVAs were conducted on age (young versus elderly) and visual condition (EO/EC), with the last factor considered as repeated measure; the dependent variables were COP RMS, COP speed, and linear displacements of head, shoulder, hip, and knee. For the experimental tasks, we computed the mean values across trials within each condition. These mean values were then subjected to three-factor ANOVAs, having as factors age, visual task, and target distance, with visual task and target distance as repeated measures; the dependent variables were the same as listed above. Post hoc comparisons were performed using the Sidak test. Mean values and standard deviations were computed for outcome variables. To accommodate for the multiple testing performed here, an alpha level of 0.01 was used for all statistical tests which were performed using SPSS version 13.0.

Results

EO and EC Conditions: Effects on Postural Sway

Regarding the EO and EC conditions, in general, the elderly group exhibited more postural sway than the young group, and the sway was greater in the EC condition. Figure 1 shows mean ± SE values of COP RMS and COP speed variables for both AP and ML directions and for the EO and EC conditions. ANOVA revealed a main effect of age on COP speed in the AP direction [$F(1,22) = 19.9$, $p < 0.001$] and also a main effect of vision on the same variable [$F(1,22) = 35.7$, $p < 0.001$]. There was a significant interaction between age and vision on COP speed in the AP direction [$F(1,22) = 9.7$, $p = 0.005$]. Post hoc comparisons revealed that the elderly adults presented significantly higher COP speed values than the young adults in both visual conditions ($p < 0.001$ for both) and that only the elderly adults presented significantly higher COP speed values in the EC than in the EO condition ($p < 0.001$). ANOVA revealed a main effect of vision on COP speed in the ML direction [EO = 0.34 ± 0.01 cm/s, EC = 0.39 ± 0.02 cm/s; $F(1,22) = 11.6$, $p = 0.003$]. Figure 2 shows mean ± SE values for the linear displacement variables in the AP direction and for the EO and EC conditions. ANOVA also revealed a main effect of age on the linear displacement of the head [young 2.72 ± 0.25 cm, elderly 3.72 ± 0.25 cm; $F(1,22) = 7.61$, $p = 0.001$].

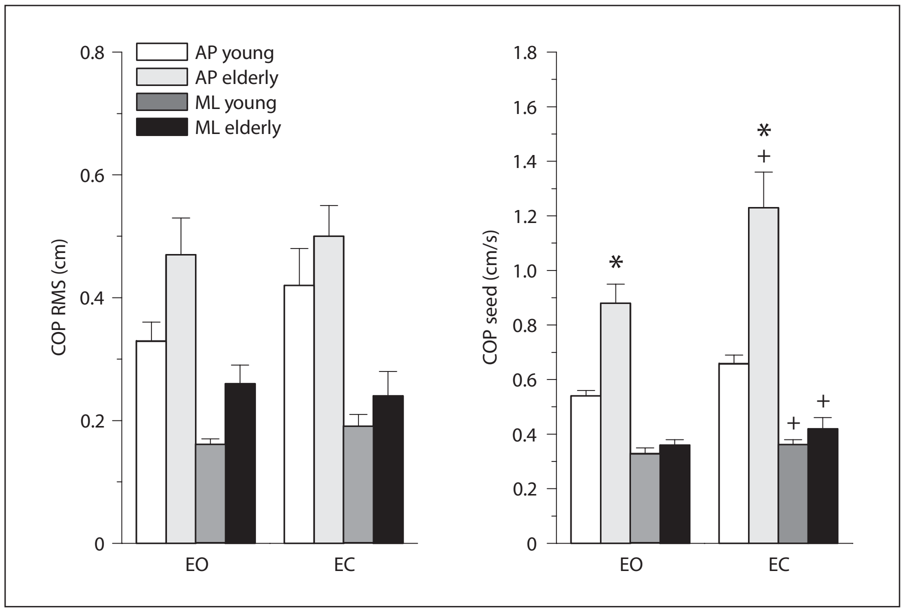

Fig. 1. Mean ± SE values for the young adult and elderly adult groups of COP RMS and COP speed for AP and ML directions for the two visual conditions EO and EC. Significant differences between age groups (* $p < 0.01$) and between visual conditions within age groups (+ $p < 0.01$).

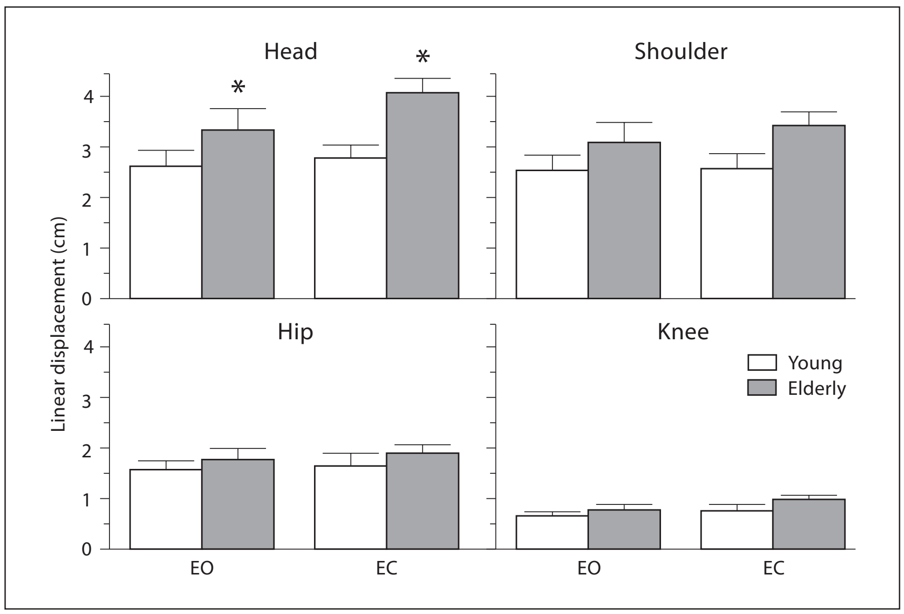

Fig. 2. Mean ± SE values for the young adult and elderly adult groups of the linear displacements in the AP directions of head, shoulder, hip, and knee for the two visual conditions EO and EC. Significant differences between age groups (* $p < 0.01$).

Suprapostural Tasks: Effects on Postural Sway

Visual Performance. The mean proportion correct during the search task was 91.1 ± 5.1% for the young group and 87.5 ± 7.1% for the elderly group, and a t test revealed that there was no difference between groups [$t(22) = 1.42$, $p = 0.16$]. However, the elderly group was slower in counting the number of letters during the search task [young 62 ± 2 letters, elderly 50 ± 4 letters; $t(22) = 7.67$, $p < 0.001$].

Effect of Age. The elderly group exhibited more sway than the young group. Figure 3 shows mean ± SE values of COP RMS and COP speed variables in both AP and ML directions and for all conditions. ANOVA revealed a main effect of age on COP RMS in the ML direction [young 0.14 ± 0.02 cm, elderly 0.23 ± 0.02 cm; $F(1,22) = 7.6$, $p = 0.01$] and on COP speed in the AP direction [young 0.50 ± 0.04 cm/s, elderly 0.69 ± 0.04 cm/s; $F(1,22) = 9.0$, $p = 0.007$].

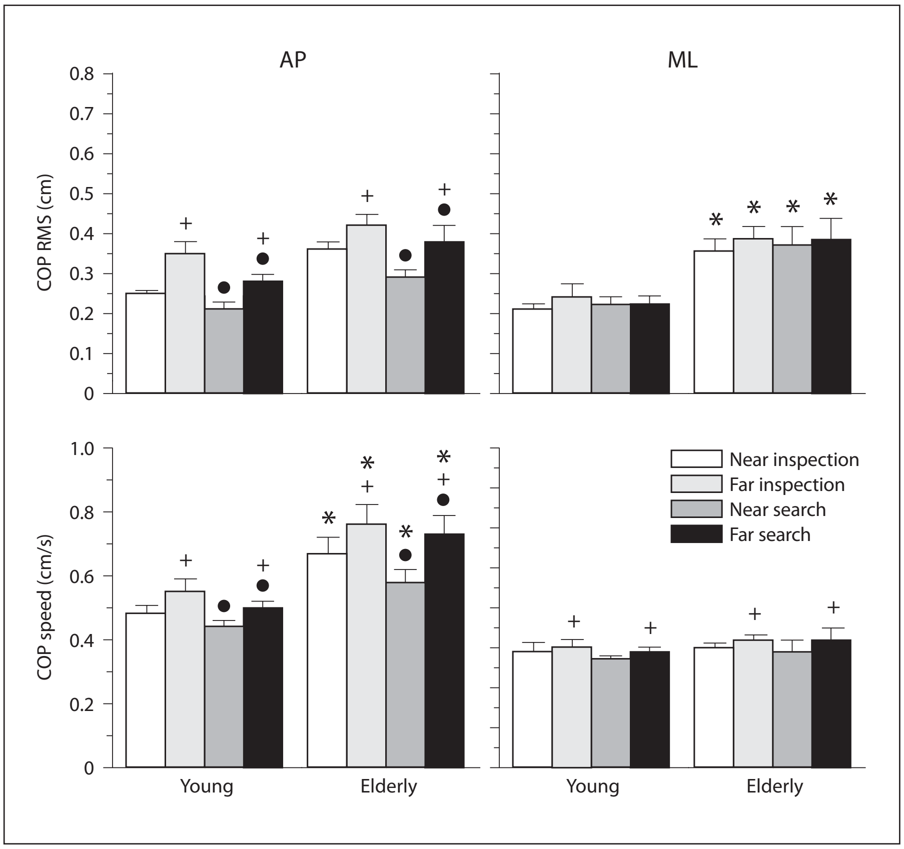

Fig. 3. Mean ± SE values for the young adult and elderly adult groups of COP RMS and COP speed for AP and ML directions for all four tasks (near inspection and far inspection and near search and far search). Significant differences between age groups (* $p < 0.01$), between factor distance within age groups (+ $p < 0.01$), and between factor target within age groups (• $p < 0.01$).

Effect of Target Distance. For both COP and kinematic variables, sway was less when viewing the near target, relative to sway when viewing the more distant target, for both age groups. Figure 3 shows mean ± SE values of COP RMS and COP speed variables in both AP and ML directions and for all conditions. There were main effects of target distance on COP RMS in the AP direction [near target 0.28 ± 0.01 cm, far target 0.36 ± 0.02 cm; $F(1,22) = 36.8$, $p < 0.001$] and on COP speed in the AP direction [near target 0.55 ± 0.02 cm/s, far target 0.64 ± 0.03 cm/s; $F(1,22) = 44.2$, $p < 0.001$] and in the ML direction [near target 0.29 ± 0.01 cm/s, far target 0.31 ± 0.01cm/s; $F(1,22) = 26.0$, $p < 0.001$]. Figure 4 shows the mean ± SE values of the linear displacement variables in the AP direction and for all conditions. There were also main effects of target distance on linear displacement of head [near target 2.17 ± 0.11 cm, far target 2.76 ± 0.15 cm; $F(1,22) = 44.3$, $p = 0.001$], shoulder [near target 2.00 ± 0.13 cm, far target 2.47 ± 0.15 cm; $F(1,22) = 52.0$, $p = 0.001$], hip [near target 1.29 ± 0.11 cm, far target 1.56 ± 0.14 cm; $F(1,22) = 25.5$, $p = 0.001$], and on the knee markers [near target 0.64 ± 0.07 cm, far target 0.74 ± 0.09 cm; $F(1,22) = 8.0$, $p = 0.01$].

Effect of Visual Task. In general, sway was reduced during the search task, relative to sway during the inspection task, for both age groups. Figure 3 shows mean ± SE values of COP RMS and COP speed variables in both AP and ML directions and for all conditions. There were main effects of suprapostural task on COP RMS in the AP direction [inspection task 0.35 ± 0.01 cm, search task 0.29 ± 0.02 cm; $F(1,22) = 17.0$, $p < 0.001$] and on COP speed in the AP direction [inspection task 0.62 ± 0.03 cm/s, search task 0.56 ± 0.03 cm/s; $F(1,22) = 22.0$, $p < 0.001$]. Figure 4 shows mean ± SE values of the linear displacement variables in the AP direction and for all conditions. The variation in suprapostural task also had main effects on linear displacements of the head [inspection task 2.64 ± 0.14 cm, search task 2.29 ± 0.13 cm; $F(1,22) = 14.3$, $p < 0.001$] and shoulder [inspection task 2.40 ± 0.13 cm, search task 2.06 ± 0.16 cm; $F(1,22) = 8.9$, $p = 0.007$].

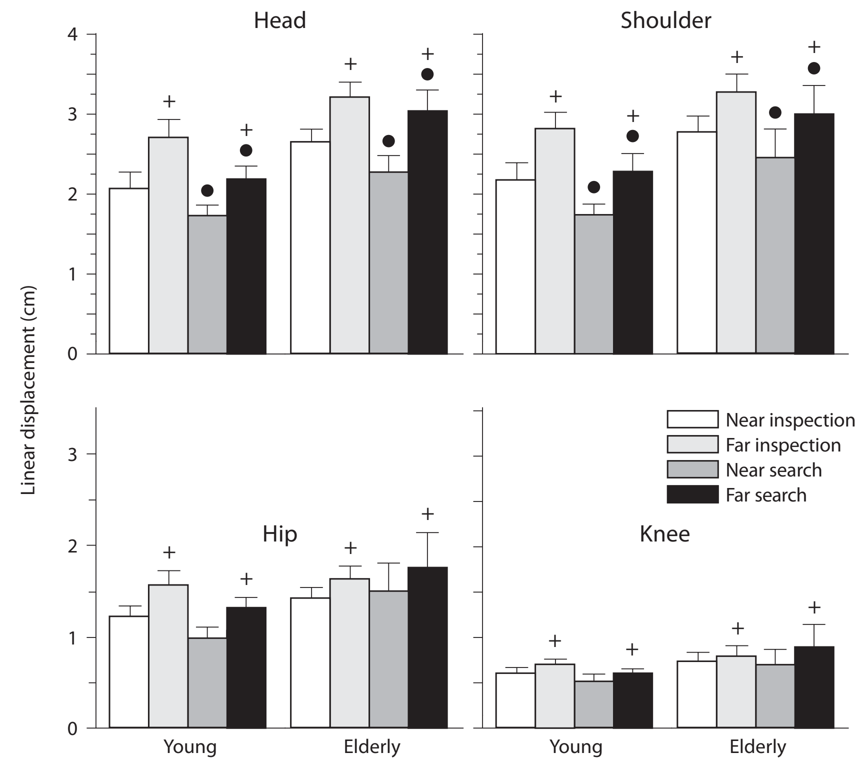

Fig. 4. Mean ± SE values for the young adult and elderly adult groups of the linear displacements in the AP directions of head, shoulder, hip, and knee for all four tasks (near inspection and far inspection and near search and far search). Significant differences between factor distance within age groups ($^{+}$ $p < 0.01$) and between factor target within age groups ($^{\bullet}$ $p < 0.01$).

Discussion

Among young adults, we replicated the effects of target distance and suprapostural task reported previously [14], i.e., reduction in body sway when looking at nearby target and in a more demanding visual task. In the absence of vision, we found an increase of the COP speed for both age groups. For young adults, the effect of vision on standing postural sway is somewhat controversial in the literature. Some authors have reported that when subjects close their eyes, their body sway increases, while others have observed no effect of vision on postural sway [for a review see ref. 22]. In the present study, when the eyes were closed, elderly subjects exhibited greater overall sway than younger subjects, replicating a common finding [3, 8]. Despite this difference in overall sway, the elderly subjects exhibited the same pattern of sway over the visual conditions as was observed among younger adults, as revealed by measurements of the COP and kinematics of body segments. Analysis of COP data revealed that the COP speed was sensitive to differences between young and elderly adults related to postural sway, in agreement with results of other studies [23–25]. The kinematic results found here are consistent with the notion that humans behave as an inverted pendulum (but not necessarily as a single pendulum) during standing. The amplitude of displacement of each body segment increased with its distance to the ground.

In both age groups, we found that the amplitude of standing body sway was reduced when subjects looked at nearby targets, relative to sway during viewing of distant targets, and was reduced during a demanding visual task (search) relative to sway during a less demanding visual task (viewing a blank target). Such findings are in contrast to results of other studies that have reported increases in posture sway for young and older adults during dual tasks involving cognitive and reaction time tasks [5–7] and even involving some types of visual information [8]. All these results suggest that the effects observed here are task specific. Our results indicate that some visual tasks constrain posture more, or simply differently, than others which may explain why differing effects of dual tasks on postural control have sometimes been reported [5–15].

Perception and control of upright stance often are assumed to be largely independent of other behavior in which people are simultaneously engaged. For example, the use of optic flow for the perception of body sway, and for the organization of postural control actions, is widely assumed to be automatic [26]. The idea that postural control is independent of other activity is consistent with the widely accepted view that there is competition for 'central processing resources' between postural control and concurrent nonpostural activity [26]. This view leads to the prediction that simultaneous postural and nonpostural activity can lead to decrements in the performance of postural control, of nonpostural activity, or both.

However, Stoffregen et al. [13, 14, 27], who observed a reduction in sway during a dual task for young adults, proposed an alternative view: the organization and execution of postural control may not be independent of concurrent nonpostural activity. They proposed there may be functional integration between postural control and simultaneous suprapostural tasks, in at least some cases. Stoffregen et al. [14] do not assume that postural control and suprapostural activity impose competing demands on central resources. Rather, they made an a priori argument that stance can be modulated in ways that facilitate the performance of some suprapostural tasks [13, 14, 27].

An alternative explanation to the reduction in postural sway during the dual task studied here is that the visual task (the nonpostural task) provided better cues to the visual perception of motion and that this information was used by the posture control system to reduce posture sway. More specifically, when the subjects had to search for letters in a target in comparison with just looking at a blank target, although the cognitive demand was increased (which could have increased postural sway), the target with text provided a scene with higher visual contrast (what could have been used by the posture control system to decrease postural sway). Under this rationale, it is possible that the observed decrease in posture sway resulted from a stronger effect of the higher visual contrast factor. This explanation does not exclude the hypothesis of functional modulation of posture sway for suprapostural tasks [13, 14], and it is possible that both factors may have accounted for the observed decrease in postural sway. Further studies have to be conducted to elucidate this question.

Conclusions

The present results support the idea that dual tasks do not necessarily lead to an increase in postural sway. In dual task with only cognitive/perceptual demands, we found exactly the opposite results for young adults and for elderly adults. Our elderly subjects appeared to integrate the control of stance with performance of suprapostural visual tasks, despite the overall increase in sway that characterizes aging. We investigated only healthy subjects; it would be interesting to investigate this effect in patients with postural deficits, such as elderly individuals with a history of falls. The present study replicated a known behavior related to aging (overall increase in postural sway) and revealed a behavior that appeared to be independent of aging (modulation of sway relative to the suprapostural tasks). It will be important to determine whether postural deficits would not only increase postural sway but also disrupt such task-specific modulation of sway.

Acknowledgments

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