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Mirror versus stationary cross feedback in controlling the centre of mass in quiet standing in elderly subjects

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Running title: Mirror feedback and postural control in elderly

Abstract

Objective. To investigate the effect of mirror feedback on postural control during quiet standing in elderly adults. **Design.** Pre and post intervention trials. **Setting.** Centre de Pneumologie Henri Bazire, Saint Julien de Ratz, France. **Participants.** Eleven elderly adults (mean age = 70.7 ± 4.6 years; mean body weight = 64.5 ± 15.0 kg; mean height = 161.4 ± 12.0 cm). **Interventions.** Participants were asked to stand upright as immobile as possible in two eyes open and mirror feedback conditions. The latter experimental condition consisted in supplying the subjects with their frontal reflected image by positioning a mirror device in front of them. **Main Outcome Measures.** Center of foot pressure (COP) displacements in the mediolateral (ML) and anteroposterior (AP) directions were recorded using a force platform. **Results.** Mirror feedback condition resulted in different effects on postural sway according to the ML or AP direction: (1) range, variability and maximal instantaneous speed of the COP displacements decreased in the ML direction, whereas (2) they remained unchanged in the AP direction. **Conclusions.** These results evidenced positive effects of mirror feedback on postural control in elderly adults that may put them at lower risks of falling.

Key words: Elderly; Postural sway; Mirror feedback.

Introduction

In recent years, a growing number of researchers have investigated the origin of falls among elderly persons (1). Indeed, falls represent one of the most serious problems associated with aging (2-4). In addition to high medical expenses that falls pose to the public health service, the consequences for elderly persons are dramatic because of their association with physical and psychological trauma, reduced activity, loss of independence, decreased quality of life and even injury-related deaths. Although falling is a complex and multifactorial problem (5-7), decreased postural control is usually considered as a major contributing factor (8-14). More precisely, posturographic parameters of mediolateral (ML) postural sway measured in unperturbed stance were shown to be the most strongly associated with a history of falls and to be the best predictors for risk of falling in an elderly population (11, 12). These findings also have been extended to dynamic situations since an increased ML body motion during obstructed locomotion was demonstrated to discriminate elderly persons at greater risk of falling (15). Therefore, it is legitimate to propose that enhancing ML postural control could be useful for preventing falls in elderly adults (16).

A technique used for improving postural control consists of supplying the subjects with visual feedback information about their own center of pressure (COP) displacements. In such a protocol, the subject stands on a force platform, the COP position is depicted in real time on a computer screen and he/she is required to confine

it to the narrowest possible area. This so-called "visual feedback technique" allowed individuals to decrease their postural sway, in both the anteroposterior (AP) and ML directions and is considered an efficient tool in the rehabilitation of patients with impaired balance (17-21). However, such a technique requires high-cost equipment not often available in rehabilitation or community-living environments. In the present experiment, we wanted to test a more readily available device aimed at decreasing ML postural sway in elderly adults.

Our purpose was to investigate whether supplying elderly individuals with their frontal reflected image by positioning a mirror device in front could modify their postural sway. It was hypothesized that elderly adults can benefit from mirror feedback for regulating their postural sway during quiet standing. In addition, given the positioning of the mirror relative to the body, different effects according to the ML or AP direction were expected, with a decreased postural sway mostly occurring in the frontal plane.

Methods

Subjects

Eleven elderly adults (mean age = 70.7 ± 4.6 years; mean body weight = 64.5 ± 15.0 kg; mean height = 161.4 ± 12.0 cm) participated in the study. Subjects were volunteers from the Centre de Pneumologie Henri Bazire (Saint Julien de Ratz, France)

and gave written consent to the experimental procedure as required by the Helsinki declaration (1964) and the local Ethics Committee. None of the subjects presented any known musculosqueletal problems, defects in the peripheral sensory system of the lower extremities, vascular pathology, neurological disorders or vestibular impairment. Finally, all subjects had normal or corrected-to-normal vision.

Apparatus

A force platform (AMTI model OR6-5-1) was used to measure displacements of the center of foot pressure (COP) by computation of the three orthogonal components of the ground reaction forces and their associated torque. Signals from the force platform were sampled at 200 Hz (12 bit A/D conversion) and filtered with a second-order Butterworth filter (10 Hz).

Task and procedures

Subjects stood barefoot, their arms hanging loosely by their sides and were asked to remain as immobile as possible. Once participants adopted the required posture and had stabilized their postural sway, the sampling was initiated. Two experimental conditions were presented. In the *Eyes open* condition, subjects were asked to fixate the intersection of a black cross placed on a white wall 1 meter in front of them, at eye level. In the *Mirror feedback* condition, subjects were able to visualize their frontal reflected image on a mirror placed on the wall distant 1 meter in front of them. Three 40-s trials for each condition were presented. The order of presentation of the two

conditions was counterbalanced across subjects. Sufficient rest time was allowed between the trials eliminating the potential for fatigue effect.

Data analyses

Several dependent variables were used to describe the subjects' postural sway. The ranges of the COP displacements (*in millimeters*) in the ML and AP directions indicate the maximal deviation of the COP displacement along the ML and AP axes, respectively. The standard deviation of the COP displacements (*in millimeters*) in the ML and AP directions gives an indication of the variability of the COP displacements over the sampled period along the ML and AP axes, respectively. Finally, the maximal instantaneous speed of the COP displacements (*in millimeters/second*) in the ML and AP directions represent the maximum value of the first derivative of the COP displacement along the ML and AP axes, respectively.

Statistical analyses were performed using Statistica for Windows (version 5). The three dependent variables were submitted to separate one-way analyses of variance (*ANOVAs*) (2 conditions (Eyes open vs. Mirror feedback) for each direction of displacement. The level of significance was set at 0.05.

Results

Figure 1 illustrates representative COP displacements from a typical subject for the two *Eyes open* (A) and *Mirror feedback* (B) conditions.

Insert Figure 1 about here

Analysis of the range of the COP displacements exhibited different results according to the ML or AP direction. An effect of condition was observed along the ML direction, with a smaller ML COP range in the *Mirror feedback* than in the *Eyes open* condition (24.6 ± 7.3 vs. 28.1 ± 8.6 mm for the *Mirror feedback* and *Eyes open* conditions, respectively, $F(1,10) = 15.23$, $P < 0.01$; Figure 2A), whereas no effect of condition was observed along the AP direction (23.1 ± 6.0 vs. 25.2 ± 9.1 mm for the *Mirror feedback* and *Eyes open* conditions, respectively, $F(1,10) = 1.73$, $P > 0.05$; Figure 2B).

Insert Figure 2 about here

Similar results were observed for the COP variability. Along the ML axis, the ANOVA showed a main effect of condition, with a smaller ML COP variability in the *Mirror feedback* than in the *Eyes open* condition (4.5 ± 1.3 vs. 4.9 ± 1.5 mm for the *Mirror feedback* and *Eyes open* conditions, respectively, $F(1,10) = 7.97$, $P < 0.05$; Figure 2C), whereas no effect of condition was observed along the AP direction (4.2 ±

1.1 vs. 4.4 ± 1.5 mm for the *Mirror feedback* and *Eyes open* conditions, respectively, $F(1,10) = 1.16$, $P > 0.05$; Figure 2D).

Analysis of the maximal instantaneous COP speed also yielded similar effects. The ANOVA applied to the maximal instantaneous COP speed along the ML direction confirmed a main effect of condition, with a slower ML maximal COP speed in the *Mirror feedback* than in the *Eyes open* condition (54.2 ± 17.9 vs. 64.5 ± 26.2 mm/s for the *Mirror feedback* and *Eyes open* conditions, respectively, $F(1,10) = 6.87$, $P < 0.05$; Figure 2E), whereas no effect of condition was observed along the AP direction (56.4 ± 24.2 vs. 60.7 ±25.9 mm/s for the *Mirror feedback* and *Eyes open* conditions, respectively, $F(1,10) = 0.88$, $P > 0.05$; Figure 2F).

Discussion

With the goal of enhancing postural control during quiet stance in elderly adults, the present experiment was designed to investigate the postural effects of a mirror feedback. Subjects were asked to stand as immobile as possible in two *Eyes open* and *Mirror feedback* conditions. The latter experimental condition consisted of supplying the subjects with their frontal reflected image by positioning a mirror device in front of them.

Our results showed that elderly adults could benefit from mirror feedback for regulating their postural sway during quiet standing. Interestingly, mirror feedback

yielded different effects on COP displacement according to the ML or AP direction: range, variability and maximal instantaneous speed of the COP displacements decreased in the ML direction, whereas they remained unchanged in the AP direction.

It is well established that individuals are able to use a visual target to control their posture during quiet standing (22-24). In the present experiment, subjects were asked to fixate their own body image to regulate their postural sway. Visual detection of body displacements along the ML direction was performed through slippage of the fixated target on the retina, whereas visual detection of body displacements along the AP direction was performed through size modifications of the image upon the retina. On the one hand, it is likely that providing frontal reflected image of the body favored the detection (and the regulation) of ML body displacements. On the other hand, during quiet standing and with an eye-target distance of 1 m, body oscillations along the AP direction are probably not large enough to notably modify the size of the image upon the retina and to affect postural control in the AP direction. In other words, the contrasting effects observed in the mirror feedback condition according to the ML and AP directions could be referred to the different thresholds of visual detection of the body movements in the ML and AP directions (25). It remains however that manipulating the distance between the observer and the mirror or the reflected image size would probably modify the effects observed in the present experiment (22, 23, 26).

In conclusion, the observed changes in COP data suggested that mirror feedback technique increased the effectiveness of postural control in elderly persons in the ML direction. Although this constitutes an initial finding with potentially useful applications for low-cost therapy, much more extensive research is needed before it would be possible to conclude that the mirror feedback technique has value as a method of rehabilitation. For instance, there is no evidence of any carry-over effect beyond the experiment. Work investigating whether and how elderly persons or persons with some pathology could benefit from mirror feedback training programs for improving their balance control, is planned.

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Figure captions

Figure 1. Representative displacements of COP from a typical subject in the two Eyes open (*A*) and Mirror feedback (*B*) conditions.

Figure 2. Mean and standard deviation for the range (*A,B*), variability (C,*D*) and maximal instantaneous speed (*E,F*) of the COP displacements for the two Eyes open and Mirror feedback conditions. The two experimental conditions are presented with different symbols: Eyes open (*white bars*) and Mirror feedback (*black bars*). Left and right panels represent mediolateral (ML) and anteroposterior (AP) directions, respectively. The significant *P* values for comparison between Eyes open and Mirror feedback conditions are reported.

Figure 1

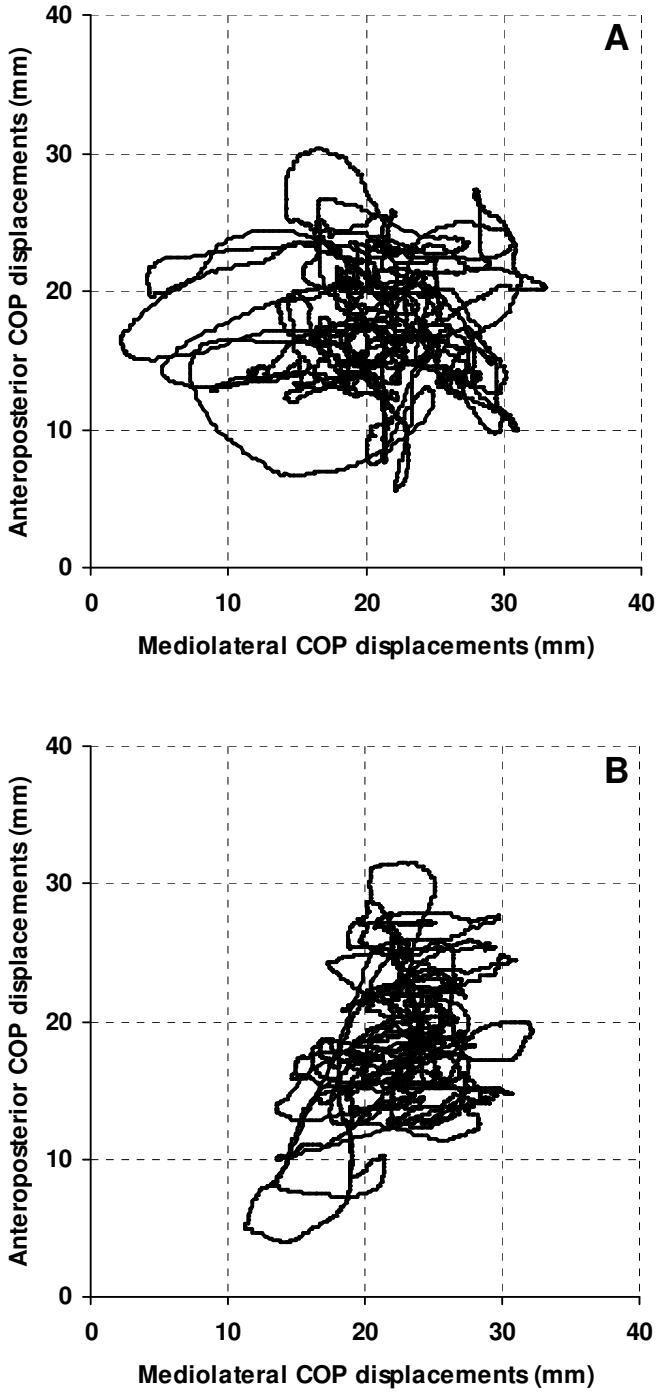
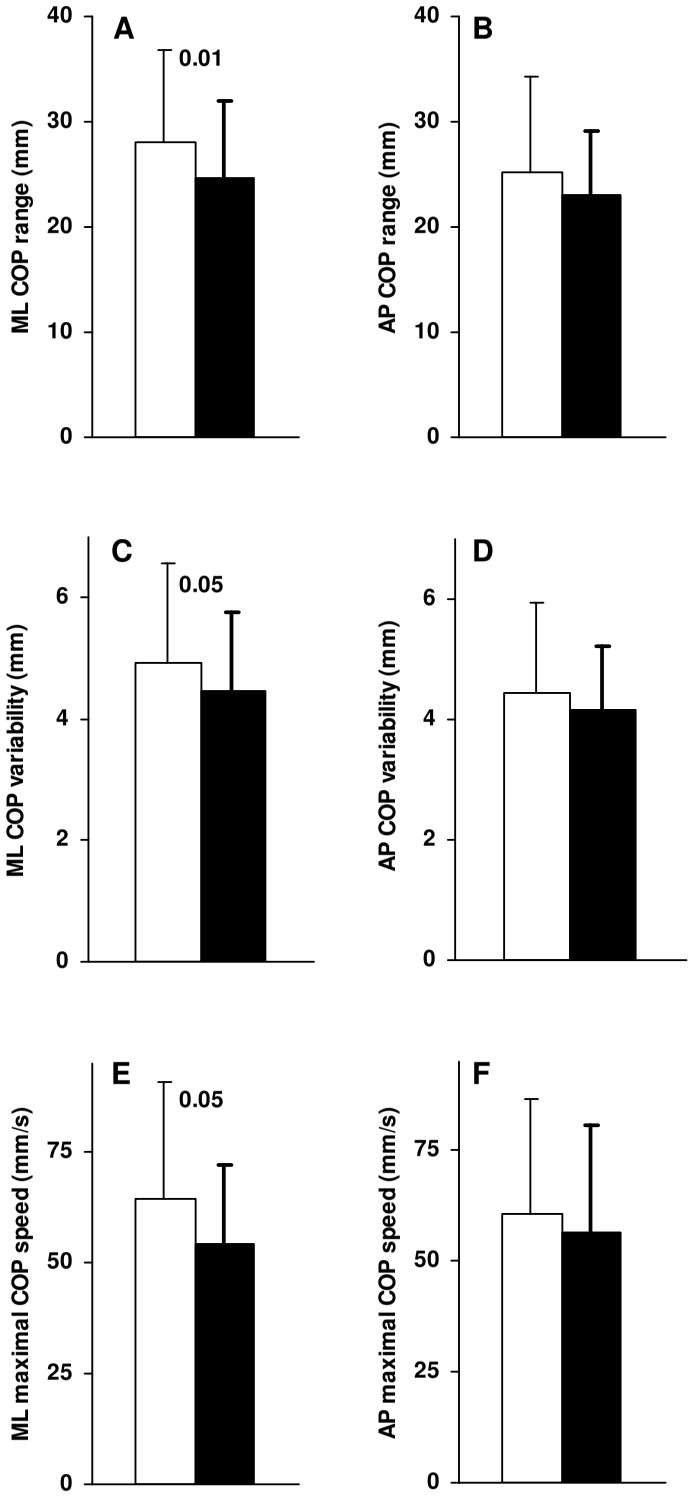

A
B
Anteroposterior COP displacements (mm)
Mediolateral COP displacements (mm)
0
10
20
30
40

Figure 2


A
0.01
ML COP range (mm)
40
30
20
10
0
B
AP COP range (mm)
C
0.05
ML COP variability (mm)
6
4
2
D
AP COP variability (mm)
E
0.05
ML maximal COP speed (mm/s)
75
50
25
F
AP maximal COP speed (mm/s)