Effectiveness of fingertip light contact in reducing postural sway in older people

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Abstract

Background and objective: haptic cues from fingertip light touch (LT) with a stationary surface reduce postural sway even at non-mechanically supportive force levels. Aim of this study was to determine the effects of LT on postural sway in older compared with younger persons.

Subjects: twenty young (age 20–29, mean 23.9 + 2.5) and 20 older participants (age 65–83, mean 74.3 + 6.4).

Methods: subjects stood in the semi-tandem position on a firm surface, and their postural sway was quantified using a force platform. Experimental trials, randomised across subjects, included two sight conditions (vision and no vision) and three contact conditions (no touch, NT; light touch, LT; and force touch, FT). The measured parameters were the length and the area of centre of pressure sway (COP-L and COP-A) and the mean velocity of COP displacements in the anterior–posterior (COP-AP) and medial–lateral (COP-ML) direction.

Results: for all variables, the analysis showed significant differences between contact conditions, sight conditions and age. Contact–age interaction was significant between NT and LT conditions, with older participants showing greater decrease in postural sway than younger participants, but not between FT and LT conditions.

Conclusions: results indicate that the effectiveness of LT in reducing postural sway may be greater in older than in younger persons, perhaps because in older persons haptic cues from upper extremity might counterbalance sub-clinical sensory loss in the lower extremities. This finding supports the hypothesis that older people may sometimes use a walking aid as an informative device and suggests that during balance training external aids should not be used.

Keywords: haptic cues, fingertip contact, postural sway, older people, elderly

Introduction

The combination of cutaneous and kinesthetic inputs from mechanoreceptors embedded in the skin, muscles and joints of the hand and arm, known as the haptic sense [1], is critical for complex sensorimotor skills, such as object recognition through exploration [2], handling [3] and grasping [4]. Recently, haptic information has been found to be also important for human postural control. In the early 1990s, Holden, Ventura and Lackner [5] and Jeka and Lackner [6] found that a fingertip touch on a stationary surface could attenuate postural sway in normal individuals even when the level of force applied was mechanically inadequate to influence body motion. A reduction in postural sway equivalent to that induced by sight of the surroundings was obtained by a level of force lower than 1 Newton. The authors hypothesised that stabilisation of posture was accomplished in a completely different way when the participant used light rather than force touch, and the timing of finger contact forces and body sway strongly supported their suggestion. Indeed, body sway and fingertip forces were essentially in phase with force contact, suggesting that fingertip contact forces were physically counteracting body sway. With light touch (LT) contact, on the contrary, much longer time delays between body sway and fingertip forces were observed, suggesting the existence of a feedforward mechanism in which fingertip cues trigger the activation of postural muscles to control body sway [6].

These findings have been confirmed by several researchers who have shown the effectiveness of LT in reducing postural sway in many stance conditions, ranging from quiet stance [7, 8] to inherently unstable postures such as tandem Romberg [9, 10], as well as in dynamic conditions such as treadmill walking [11].

These results have clinical implications for understanding how patients may benefit from fingertip contact...
to compensate postural instability. Only few studies have investigated this issue in subjects with impairment of balance, but so far results were similar to those obtained in healthy young people. LT has proved to be highly effective during quiet stance in patients with bilateral vestibular loss [12] or with peripheral neuropathy [13]. However, neuropathic patients could not improve the scaling of automatic postural responses by light contact during backward translations of the support surface at different speeds [14].

Despite the relevant changes in postural stability associated with ageing [15, 16], the influence of fingertips contact on postural sway has not been extensively investigated in older people. Two studies have reported data derived from older subjects [17, 18], indicating that haptic cues are not used differently by different age groups. Tremblay et al. [18], however, whose subjects were not constrained to exert contact force lesser than a threshold during LT trials, found that older people tended to use greater forces compared with young subjects.

The aim of this study was to verify the hypothesis that when kinesthetic inputs from lower limbs are not artificially distorted by a foam or a moving support surface, the beneficial effect of fingertip contact on balance control may be higher in older than in younger persons. This hypothesis is consistent with the notion that the loss of sensory information from lower limbs is a major cause of postural instability in older persons [19], and haptic cues from the hand might represent a powerful compensation in such conditions.

**Method**

**Subjects**

Twenty young participants, 12 women and 8 men, with a mean age of 23.9 ± 2.5 (range 20–29), and 20 older participants, 11 women and 9 men, with a mean age of 74.3 ± 6.4 (range 65–83), were enrolled in the study. None had a known history of neurological or musculoskeletal disorder that might have influenced their balance, and neither did they have serious sight problems. All gave their written informed consent.

**Procedure**

The subjects stood in the semi-tandem position (heel of the left foot at the level of the fifth metatarsal head of the right foot) on a firm surface while using different levels of support from the right hand. The postural sway response was quantified using the underfoot centre of pressure (COP) measure, calculated from the forces and moments obtained from a force plate (AMTI, Advanced Mechanical Technology Inc., Massachusetts, MA, USA; model OR6) digitised at 50 Hz. To control the force exerted through the upper extremity, subjects were told to put their right index finger on a touch-sensitive plate, placed laterally on a table at the subject's waist level. An auditory tone was generated when a force higher than a preset threshold was applied. There were six experimental conditions. Three levels of applied force through the upper extremity were used: (i) No touch (NT), where subjects stood with both arms at the waist. (ii) Light touch (LT), where subjects were limited to a maximum of 1 N of applied force through right index finger. (iii) Force touch (FT), where subjects were directed to exert as much pressure as necessary to stand steady through their right index finger on a stable surface.

The trials were repeated with two sight conditions: (i) eyes open (EO), where the subjects had to look at a mark set at eye level, at a distance of 2 m and (ii) eyes closed (EC). For each experimental condition, one trial of 20 s was performed, with a 2-min rest period between trials, during which subjects remained seated. The order of touch conditions and the order of EO and EC trials were randomised across subjects.

Before a trial, subjects were informed about the task. Then they were told to look straight ahead and to take as much time as desired to reach a steady condition. Once they felt stable, on average 15 s after the beginning of upright posture, the examiner started the data acquisition. However, subjects were not aware of the exact moment at which data recording started. Before LT trials, participants practised for 2 min with the device to learn how to apply the desired force without setting the alarm off. LT trials were repeated if the subject was unable to complete them without setting the alarm off more than once.

**Data analysis**

To avoid anticipation effects associated with the beginning and the end of a trial, the first and the last 2.5 s of data were excluded from the analysis, leaving 15 s of data for each trial. It has been previously demonstrated that a single 15 s recording of postural sway in older people has a good test-retest reproducibility [20]. The measured parameters consisted of the length of COP sway (COP-L), the area of COP sway (COP-A) and the mean velocity of COP displacements in the medial–lateral (COP-ML) and anterior–posterior (COP-AP) directions. We used mean velocity of COP displacements since it has been proved that this parameter is the most reliable measure of postural sway [21]. For each variable, LT/NT and FT/LT ratios (ratio between postural measures recorded during LT and NT trials, and during FT and LT trials, respectively) were also calculated. An analysis of variance (ANOVA) with repeated measures with two factors, age (two levels) and vision (two levels), was used to detect differences during NT, LT and FT trials. One-way ANOVA was used to detect differences in LT/NT and FT/LT ratios between groups. Three 2 × 2 × 2 ANOVA with repeated measures were then conducted to examine the effects of touch (LT versus NT, FT versus LT and LT/NT versus FT/LT ratios), vision (EO and EC) and age (young and older) factors and their interactions on postural sway. Data analyses were performed using the SPSS statistical package 12.0 for Windows.
Results

Age-related differences

In NT trials, the older group showed greater postural instability than young subjects, as indicated by significantly higher values of all the COP sway measures ($P<0.001$). Postural sway also increased in the absence of vision ($P<0.001$) in both age groups. The age–vision interaction that resulted was always statistically significant (COP-A, $P<0.005$; COP-L, COP-ML and COP-AP, $P<0.001$), indicating that the effect of removing the vision input on postural sway was significantly higher in the older than in the younger participants during NT trials.

Effect of contact conditions

Variations in touch condition significantly affected postural sway (Table 1 and Figure 1). LT was indeed highly effective in reducing postural sway with respect to NT trials, especially with EC, although FT produced a significant further stabilisation.

For all the variables studied, differences between LT and NT conditions were highly significant ($P<0.001$), with a significant vision–touch interaction ($P<0.001$). Moreover, we found significant interactions between age and touch ($P<0.001$) and between age, vision and touch ($P<0.001$ for COP-L and COP-ML, $P<0.005$ for COP-A and COP-AP), indicating that haptic cues from hand and arm had a slightly different effect in the two age groups. Figure 1 illustrates how in older subjects postural sway was extremely decreased during fingertip light contact, which consequently reduced the differences between the two groups.

When comparing LT and FT data, differences between touch conditions were also found ($P<0.001$), with a significant vision–touch interaction for COP-A ($P<0.01$), COP-L ($P<0.05$) and COP-ML ($P<0.01$). However, the age–touch and the age–touch–vision interactions were never significant.

The ratios between postural measures in LT and NT trials (LT/NT) and between postural measures in FT and LT trials (FT/LT) are summarised in Table 2. These ratio values synthetically represent the reduction in postural sway induced by light contact compared with the baseline condition and the further reduction caused by force contact, respectively. In general, for all postural measures LT/NT ratios were lower than FT/LT in both age groups ($P<0.005$). As regards age-related differences, we found a significant age–ratio interaction for COP-A ($P<0.05$) and COP-ML ($P<0.005$), and a significant age–ratio–vision interaction for COP-L, COP-ML and COP-AP ($P<0.02$). On average, LT/NT ratios were lower in the older group, especially for trials in the absence of vision, but such differences were not significant ($P=0.054$ for COP-L and $P=0.59$ for COP-ML, trials with EC). Conversely, FT/LT ratios were lower in the young than in the older group when trials were performed in the absence of vision ($P<0.001$ for COP-ML and $P<0.01$ for COP-A and COP-L).

Discussion

The present findings confirm the notion that in healthy older persons, haptic cues from the fingertip contact provide a sensory information that helps to reduce postural sway, especially in the absence of vision. In both our age groups, postural stability in the LT-EC and in the NT-EO conditions was quite comparable, indicating that sensory cues from upper arm and hand can thoroughly compensate the loss of visual information.

Table 1. Means ± SE of postural sway in the young and older groups in the different touch and sight conditions

<table>
<thead>
<tr>
<th></th>
<th>Eyes open</th>
<th>Eyes closed</th>
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<tr>
<td></td>
<td>Young people</td>
<td>Older people</td>
</tr>
<tr>
<td>COP-L</td>
<td></td>
<td></td>
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<tr>
<td>NT* *** ****</td>
<td>20.8 ± 0.9</td>
<td>31.5 ± 2.5</td>
</tr>
<tr>
<td>LT* **</td>
<td>14.4 ± 0.6</td>
<td>20.8 ± 1.6</td>
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<tr>
<td>FT* *** ****</td>
<td>11.1 ± 0.5</td>
<td>14.4 ± 1.1</td>
</tr>
<tr>
<td>COP-A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NT* *** ****</td>
<td>2.81 ± 0.25</td>
<td>5.49 ± 0.96</td>
</tr>
<tr>
<td>LT*</td>
<td>1.33 ± 0.14</td>
<td>1.91 ± 0.25</td>
</tr>
<tr>
<td>FT* *** ****</td>
<td>0.68 ± 0.8</td>
<td>1.02 ± 0.13</td>
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<tr>
<td>COP-ML</td>
<td></td>
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<tr>
<td>NT* *** ****</td>
<td>0.87 ± 0.04</td>
<td>1.38 ± 0.11</td>
</tr>
<tr>
<td>LT* **</td>
<td>0.56 ± 0.03</td>
<td>0.81 ± 0.05</td>
</tr>
<tr>
<td>FT* *** ****</td>
<td>0.37 ± 0.02</td>
<td>0.55 ± 0.04</td>
</tr>
<tr>
<td>COP-AP</td>
<td></td>
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<tr>
<td>NT* *** ****</td>
<td>0.91 ± 0.05</td>
<td>1.31 ± 0.11</td>
</tr>
<tr>
<td>LT*</td>
<td>0.66 ± 0.03</td>
<td>0.95 ± 0.09</td>
</tr>
<tr>
<td>FT* *** ****</td>
<td>0.57 ± 0.02</td>
<td>0.67 ± 0.05</td>
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COP-A, area of centre of pressure sway; COP-AP, mean velocity of centre of pressure displacements in the anterior–posterior direction; COP-L, length of centre of pressure sway; COP-ML, mean velocity of centre of pressure displacements in the medial–lateral direction; FT, force touch; LT, light touch; NT, no touch.

* $P<0.001$, vision.

** $P<0.01$, age.

*** $P<0.01$, age × vision.
In addition, our results indicate that older subjects may benefit even more than young subjects from light fingertip contact. In fact, we found a significant age–touch interaction for all the measured postural parameters. This finding has never been previously reported, but it is not unexpected when considering that in NT trials older subjects showed...
significant reduction in postural stability when compared with the young group. Changes in postural control associated with ageing are well documented [15, 16], as well as the influence of sensory deficits in lower limbs for the observed instability [19, 22, 23]. For example, it has been found that on a firm surface postural sway in older subjects is significantly associated with only one sensory measure, i.e. proprioception in the lower limbs [19], and that the absence of visual input is associated with a poorer postural stability [22]. In the very elderly, the loss of sensory cues of lower-limb pressure receptors and the deterioration in function of stretch reflexes strongly affect the postural control, so the subject seems to rely on visual input to balance [23]. Our findings seem to be consistent with other research, which demonstrated that the influence of fingertip contact may be enhanced in more demanding tasks, when kinesthetic cues from lower limbs are inaccurate. LT has proved to be more effective when the floor is sway-referenced, i.e. when the support surface moves forward and backward in the same direction as body sway [17] and when subjects stand on a foam surface [18, 24]. It has also been found that haptic contact of the hand with a stable surface can suppress abnormal proprioceptive and motor signals in leg muscles that are triggered by vibratory stimulus applied to calf muscles [25] and can compensate for the increased postural sway induced by lower-limb muscular fatigue [26]. As we tested postural sway during stance on a firm support platform, the greater decrease in the measured parameters observed in the older group during LT trials could reflect the presence of sub-clinical sensory deficits in this population that were compensated by the availability of haptic information.

The investigations conducted so far with older participants, on the contrary, studied the effect of LT under several different conditions, including a foam support surface [18] or a sway-referenced support platform and a touch-sensitive plate that was also sway-referenced [17]. The absence of a significant age–contact condition interaction may result from the protocol used. When standing on a foam or a moving support surface, the kinesthetic information from lower limbs is artificially distorted, and consequently the possible odds between the two age groups are minimised. If the touch-sensitive plate is sway-referenced, haptic information is distorted in turn. When participants lightly touched a plate that moved forward and backward in synchrony with body sway, in fact, postural sway has been found to increase, in old as well as in young subjects [17].

Since precision contact of the fingertip reduces postural sway of individuals with bilateral vestibular loss [12], an alternative explanation for the observed results is that the older participants in the present study might have been suffering from sub-clinical vestibular impairment. However, since we did not measure either lower-limb sensation or labyrinthine function in our older participants, these hypotheses cannot be empirically verified.

Though capable of cutting postural sway by half with respect to NT trials, fingertip light contact was, however, less effective than FT. This finding was somewhat expected because when subjects are allowed to apply as much force as possible on a support, the fingertip contact physically stabilises the body by widening the base of support. Nevertheless, it is worthy of note that the further reduction of body sway when subjects proceeded from LT to FT condition was generally lesser than stabilisation due to LT, especially for older subjects in the no-vision condition. In addition, young subjects were able to minimise postural sway by FT to a similar extent with EO or EC, contrary to older subjects whose postural sway in the FT–no-vision condition was comparable with postural sway in the LT–vision condition. A possible explanation of this phenomenon is that old subjects might have been applying lower forces during FT trials compared with the younger group, most likely because of trouble or painful sensations when placing a large quantity of weight on their index finger. This hypothesis cannot be tested, as we did not measure how much force subjects were applying on the plate during LT and FT trials. Alternatively, it may well be that, when visual information is not available, older people are not able to stand as steady as young individuals in the relatively unstable semi-tandem posture, even with the support of an upper extremity.

The present findings are important for understanding how older patients with poor postural control may benefit from a cane for postural stability in stance. The ownership of walking-assistive devices increases by age, and nearly 40% of >75-year-olds own a cane [27]. One may speculate that when considering only its biomechanical effect, the potential role of a cane may be underestimated. Many older people, indeed, use walking aids in a mechanically improper way, for example they use a cane of excessive length or do not move the cane in the right pattern with respect to the step sequence. Under such circumstances the cane could be used as an informative rather than a supportive device. Though some evidence exists about such feasible use of the aid [28], the issue has not been investigated in older subjects, and future studies wishing to verify this hypothesis should consider the application of LT by a cane rather than directly by fingertip contact on the touch plate.

More importantly, our findings suggest that an external aid, even when the force applied is at the lowest levels, dramatically reduces the challenge to the postural control system. Thus, physical therapists and trainers should minimise the use of external supports during rehabilitation programmes aimed at improving balance control.

**Key points**

- Fingertip light contact with a stationary surface reduces postural sway.
- The effectiveness of light contact may be even greater in older people, counterbalancing sub-clinical sensory loss in the lower extremities.

**Conflicts of interest**

None.
Fingertip contact and postural sway in older people

References


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