Postural, physiological and psychological reactions to challenging balance: does age make a difference?

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Abstract

Objectives: to determine if increases in balance challenge influenced concomitant change in self-efficacy, state anxiety and physiological arousal, and if these changes were correlated with changes in standing balance in young and older adults.

Design: a 2 × 2 between- (age) by within-subject (balance challenge) factorial design.

Setting: quiet standing trials were performed on low and high support-surface heights in a research laboratory.

Subjects: 14 young (22–31 years) and 14 older (60–83 years) adults with no known neurological or balance disorders, or falls within the last year.

Methods: forceplate-derived measures of standing balance, measures of state anxiety, blood pressure and task-specific balance and coping self-efficacy.

Results: independent of age, mean position, amplitude and frequency of centre of pressure displacements were significantly influenced by surface height, as were anxiety and efficacy. Decreased amplitude and increased frequency changes observed in both age groups with increased balance challenge were consistent with a stiffening strategy. Blood pressure, state anxiety and self-efficacy were correlated with different postural control changes in young and older adults.

Conclusions: older adults used the same stiffening strategy as young adults to cope with the increased anxiety and lowered confidence associated with standing on a high surface. Converging evidence indicates that physiological status, state anxiety and balance efficacy are related to specific changes in postural performance with increased balance challenge. Findings highlight the potential additive effects of psychological and physiological factors on clinical balance performance and the need to consider comprehensive rehabilitation and prevention techniques that concern psychological and physiological contributions to balance deficits.

Keywords: ageing, balance control, centre of pressure, efficacy, anxiety, elderly

Introduction

In older adults, alterations in behaviour, including changes in balance control, and falls, have been associated with the term ‘fear of falling’ and with restricted activity, decreased independence and quality of life [1–3]. Given the inference that fear of falling and related concepts such as low balance confidence may lead to falls and injuries, there is an important need to better understand the link between the concept of fear of falling and balance instability in older adults.

Age-related changes in standing balance control have been previously documented [4]. Although balance control changes in older adults are normally attributed to underlying physiological factors [5], psychological factors such as fear of falling and low balance confidence (i.e. balance efficacy) may also contribute to balance control changes in the elderly [3]. Associations between fear and balance performance have been found in studies that compared older adults with or without a fear of falling and/or low balance confidence [3, 6, 7]. However, there are a number of limitations of these previous studies, that may have contributed to the mixed results and limited trends that were observed, thereby preventing meaningful interpretations of the findings. One
Ground reaction force and moment data were recorded in Healthy young (9 males, 5 females, mean age = 24.6 years) and older adults (6 males, 8 females, mean age = 69.4 ± 7.3 years) volunteered to participate. The design was a 2 × 2 between-(young/old) by within-(highest/lowest balance challenge) subject factorial. Before testing, all participants read and signed an informed consent and were instructed of the procedures approved by a university research ethics board. No participants reported any falls in the previous year. Older adults were healthy, independent-living individuals that were moderately physically active at least twice per week for more than 30 min (e.g. steady walking or equivalent). Older participant co-morbidities included mild cardiovascular problems (n = 9) and joint pain (n = 8), with 10 having one and 7 having two co-morbidities. There were no neurological or balance disorders as verified by medical history and clinical balance tests. During testing, one elderly participant displayed extreme fear of heights and was excluded (n = 13).

**Methods**

**Participants and design**

Healthy young (9 males, 5 females, mean age = 24.6 ± 2.8 years) and older adults (6 males, 8 females, mean age = 69.4 ± 7.3 years) volunteered to participate. The design was a 2 × 2 between- (young/old) by within- (highest/lowest balance challenge) subject factorial. Before testing, all participants read and signed an informed consent and were instructed of the procedures approved by a university research ethics board. No participants reported any falls in the previous year. Older adults were healthy, independent-living individuals that were moderately physically active at least twice per week for more than 30 min (e.g. steady walking or equivalent). Older participant co-morbidities included mild cardiovascular problems (n = 9) and joint pain (n = 8), with 10 having one and 7 having two co-morbidities. There were no neurological or balance disorders as verified by medical history and clinical balance tests. During testing, one elderly participant displayed extreme fear of heights and was excluded (n = 13).

**Measures**

Ground reaction force and moment data were recorded in three planes from the forceplate with a sampling frequency of 20 Hz for 120 s. From each record, continuous displacement of centre of pressure (COP) was calculated offline in anterior–posterior (AP) and medial–lateral (ML) directions. COP records were filtered using a dual-pass Butterworth filter with an effective cut-off frequency of 5 Hz. From the filtered records, COP summary measures, standard deviation (SD), mean position (referenced to the ankle joint) were calculated independently in AP and ML directions [15].

Blood pressure (BP) measured from the index finger of the non-dominant hand using a pneumatic finger cuff (Ohmeda 2300, FINAPRESS) and sampled at 100 Hz was used as an indicator of physiological arousal [16]. Initial rest BP values were recorded for 60 s while subjects were standing quietly at ground level. Subsequent records were taken during the duration of each 120-s stance trial. Mean BP values were calculated offline over the first 30 s for each 120-s record and referenced to the initial rest BP value [16].

State anxiety measures, contextually modified from Smith et al. [17], were assessed immediately after completion of each standing condition. Three scales probed different elements of state anxiety: somatic (6 items), worry (4 items) and concentration/disruption (6 items). Participants scored each item using a 9-point interval scale, ranging from 1 (‘I did not feel this at all’) to 9 (‘I felt this extremely’). All item scores for a scale were summed for each of the three anxiety scales [12].

Four distinct elements of balance-related, coping self-efficacy were rated on an interval scale with 10-point increments between 0 (no confidence) and 100 (complete confidence) [18]. Before standing at any heights, subjects were required to estimate their coping efficacy in their abilities to (i) avoid a fall, (ii) maintain concentration, (iii) overcome worry and (iv) reduce nervousness during 2 min of standing at each surface height.

One measure of task-specific balance efficacy was assessed just before the performance of each stance trial (height). Subjects were required to estimate their confidence in their ability to balance while standing at the specific height for 2 min with their eyes open, on a scale with equal intervals of 10-point increments between 0 (no confidence) and 100 (complete confidence) [18].

**Procedures**

Balance challenge was manipulated through alterations in the vertical height of the support surface. A portable AMTI 6 channel forceplate, mounted to a planed marble base (total height = 19 cm), was placed on a hydraulic platform (Pentalift Pro Series, 110 × 220 cm). A wooden surround (19 cm high) was placed around the forceplate to provide a flush surface with the top of the forceplate. It extended 35 cm to each side and 38 cm in front of the forceplate.

Subjects were first seated on the hydraulic platform and allowed to experience five different surface heights (40, 70, 100, 130 and 160 cm), after which they completed a coping-efficacy questionnaire. Subjects then performed a baseline stance trial at the 40-cm height condition, followed by a random presentation of each of the remaining surface heights to avoid the influence of first trial and order effects [11].

At each surface height, subjects first rated their task-specific balance efficacy and then performed a 120-s quiet
stance trial with their arms crossed, their toes at the anterior edge of the forceplate and their feet positioned within a box with dimensions equal to their foot length. All trials were performed with eyes open and fixated on a coloured target (20 × 30 cm) located at eye level on a white wall approximately 6 m in front of them. During each stance trial, forceplate and BP measures were collected. Subjects were provided a 2-min rest period between each stance trial to minimise fatigue, during which time they completed a state-anxiety questionnaire based on the previous standing experience. No harness system was used; however, two spotter were present to prevent any loss of balance.

Statistical analyses

For the initial 40-cm stance condition, age-related differences in summary measures of COP were compared using t-tests. Alpha level was corrected for multiple comparisons (5) to 0.01, with P-values between 0.01 and 0.05 considered as trends.

Analyses of the effects of balance challenge and subject age were restricted to the extreme standing height conditions (160 and 70 cm). Three separate multivariate ANOVAs were performed using the Spearman Rho procedure on data pooled across age and surface height [20]. Multiple tests performed within each group (maximum five variables: balance performance (AP-COP SD, MPF, mean position and ML-COP SD, MPF), arousal/anxiety (BP and state anxiety) and balance efficacy (one task-specific and four coping-efficacy measures)). Significant MANOVA results were post hoc analysed via univariate ANOVAs [19]. To protect against Type I error due to multiple tests performed within each group (maximum five variables), alpha was adjusted to P<0.01. Thus effects between 0.01 and 0.05 were considered as trends. Correlations between BP change, state anxiety, task specific balance efficacy, coping efficacy and balance performance measures were performed using the Spearman Rho procedure on data pooled across age and surface height [20].

Results

Baseline balance measures

As shown in Figure 1, baseline measures of AP-COP MPF and BP change were significantly larger in older compared with young adults. No other baseline COP measures were significantly different between young and older adults.

Effects of balance challenge

Figure 1 illustrates how changes in AP-COP MPF and AP-COP mean position were scaled to increased balance challenge in both age groups. AP-COP SD change was also scaled to increased balance challenge in young adults. MANOVA revealed a significant main effect of balance challenge on balance performance (Wilks = 0.405, F(5,21) = 6.171, P<0.001). Independent of age, AP-COP mean position was shifted significantly back from the platform edge during the high compared with low balance challenge (F(1,25) = 14.345, P<0.001). AP-COP MPF significantly increased during the high compared with low balance challenge condition (F(1,25) = 10.777, P = 0.003), independent of age. There was a trend for reduced AP-COP SD in the high versus low balance challenge (F(1,25) = 4.908, P = 0.036). ML-COP SD and MPF were not significantly influenced by balance challenge. There was no significant interaction between balance challenge and age on balance performance.

MANOVA revealed a significant main effect of balance challenge on efficacy measures (Wilks = 0.355, F(5,21) = 7.621, P<0.001). Balance challenge significantly influenced balance-related coping-efficacy: avoid a fall (F(1,25) = 20.148, P<0.001), maintain concentration (F(1,25) = 24.466, P<0.001), overcome worry (F(1,25) = 7.320, P = 0.012) and reduce nervousness (F(1,25) = 11.428, P = 0.002). For each, younger and older adults reported lower balance-related coping-efficacy for the high compared with low balance challenge (Table 1). Task-specific balance efficacy was also significantly influenced by balance challenge (F(1,25) = 15.168, P<0.001). Lower efficacy values were reported by both groups during the high compared with low challenge condition. There were no significant interactions between balance challenge and age observed for these measures.

All state anxiety scales were significantly correlated (r's > +0.60). Given these strong relationships, a total state anxiety score (i.e. sum of all items) was computed and used in the following analyses. MANOVA revealed a significant main effect of balance challenge on anxiety measures (Wilks = 0.681, F(2,24) = 5.632, P = 0.010). State anxiety was significantly influenced by balance challenge (F(1,25) = 10.48, P = 0.003) with significantly higher anxiety scores reported at the high compared with low challenge (mean difference = 8.4 ± 2.6). Although a significant interaction was not detected, BP increased with balance challenge in older adults (Figure 1).

Age effects

Main effects of age were observed for balance performance (Wilks = 0.571, F(5,21) = 3.150, P = 0.028) and anxiety measures (Wilks = 0.554, F(2,24) = 9.674, P<0.001). There was a trend for an age effect for AP-COP MPF (F(1,25) = 4.038, P = 0.05), with larger MPF values observed in older compared with young adults (Figure 1). State anxiety scores were significantly higher in younger compared with older adults (F(1,25) = 17.845, P<0.001; mean difference = 22.9 ± 5.4). Furthermore, there was a trend for higher BP in older compared with young adults (F(1,25) = 5.843, P = 0.023; mean difference = 17.2 ± 7.1 mmHg).

Associations between dependent measures

Blood pressure change was significantly correlated with AP-COP mean position (r = 0.332, P = 0.014), AP-COP SD (r = −0.545, P<0.001) and ML-COP SD (r = −0.304, P = 0.025). State anxiety was significantly correlated with BP (r = −0.381, P<0.001) and ML-COP SD (r = 0.352, P = 0.010). Coping-efficacy measures related to avoiding a fall (r = −0.321, P = 0.018), overcoming worry (r = −0.377, P = 0.005) and reducing anxiety (r = −0.334, P = 0.014) were all significantly correlated with AP-COP MPF. Task-specific balance efficacy was highly correlated with all coping-efficacy measures (P<0.001).
Measures of self-efficacy to perform activities of daily living, such as the Activities Specific Balance Confidence Scale [6] and Falls Efficacy Scale [21] have been commonly used to infer a fear of falling. However, substantial evidence suggests that self-efficacy is not equivalent to perceived danger or anticipated anxiety [22] and research has shown that while fear of falling and self-efficacy are associated, they are clearly separate constructs with different effects on functional performance [23–25]. Furthermore, most studies have limited their assessments to measures of general fear of falling, or self-efficacy to perform specific activities of daily living. They do not provide information regarding the situational anxiety linked to a challenge or threat to balance or to the self-efficacy about the performance of specific postural tasks being tested in an experiment. However, inferences about the links between threats to balance, fear, the confidence in avoiding falls or balancing and balance

**Table 1.** Mean ± standard error of the difference between high and low balance challenge conditions for balance-related coping-efficacy

<table>
<thead>
<tr>
<th>Measure</th>
<th>Young adults (%) difference</th>
<th>Older adults (%) difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task specific balance efficacy</td>
<td>-19.2 ± 6.9</td>
<td>-11.0 ± 3.2</td>
</tr>
<tr>
<td>Efficacy to avoid a fall</td>
<td>-9.7 ± 2.4</td>
<td>-13.1 ± 4.4</td>
</tr>
<tr>
<td>Efficacy to maintain concentration</td>
<td>-6.3 ± 2.3</td>
<td>-10.8 ± 2.7</td>
</tr>
<tr>
<td>Efficacy to overcome worry</td>
<td>-12.3 ± 6.5</td>
<td>-7.3 ± 2.4</td>
</tr>
<tr>
<td>Efficacy to reduce nervousness</td>
<td>-12.7 ± 5.1</td>
<td>-6.4 ± 2.0</td>
</tr>
</tbody>
</table>

Efficacy is assessed on a 0–100% confidence scale. Negative values indicate the difference between the efficacy perceived at the high and low heights. The higher the negative percentage value, the less confidence participants expressed for each of the balance and coping skills at the greater height. Within age categories each difference was significant (All *P*s<0.01).

**Figure 1.** Sample means and standard error bars for balance control measures and BP change in young (closed with solid black lines) and older adults (open with dashed grey lines) during 2 min of quiet stance at baseline (40 cm) and four levels of balance challenge conditions (70-, 100-, 130- and 160-cm surface heights).
performance are still made in the absence of data at one or more levels of these links. Empirical corroboration of these links is necessary.

To our knowledge, the current study is the first to experimentally vary standing surface height in order to examine the relationship between changes in physiological status, state anxiety, balance self-efficacy and performance on a postural task in young and older adults. Our observations of significant changes in BP, balance-related coping-efficacy, state anxiety and postural strategy as a function of performing at different heights provide convergent evidence confirming relationships between different forms of responses. Specifically, our experimental manipulations of balance challenge elicited changes in task- and balance-related coping-efficacy, state anxiety and BP, concurrent with change in postural strategy of young and old. Our results corroborate those found in young adults performing voluntary and reactive postural tasks at different surface heights [10, 12].

The present study has shown that elderly adults are capable of using the same postural strategy as young adults to cope with the increased anxiety and lowered confidence associated with standing on a high surface. Both age groups adopted a stiffening strategy, associated with decreased amplitude (SD) and increased frequency (MPF) of AP-COP displacement and they shifted the mean COP position backwards when standing at high compared with low heights. These observations confirm results from previous studies in healthy young adults [8, 9, 11].

Blood pressure, state anxiety and efficacy measures were strongly correlated with different postural control changes in conditions of greater balance challenge regardless of age. During quiet standing, BP change and state anxiety were highly correlated with changes in amplitude and mean position of COP displacement, whereas balance-efficacy measures were highly correlated with changes in frequency of COP displacement. An investigation strength was the use of a recommended protocol for relating self-efficacy and state anxiety to physical performance tasks such that our measures were specific and correspondent to postural tasks and situations in the experiment [18, 26]. Our observations also corroborate previous reports of strong correlations between general measures of balance self-efficacy and gait and balance performance in older adults [23, 24, 27, 28].

Despite the strengths of this study, we acknowledge that our older adults group, despite their co-morbidities, were apparently healthy, independently living, physically active and non-fallers. Thus, generalisability of results is limited to this group. Interestingly, this sample homogeneity also highlights the impact that anxiety and balance confidence can have on balance performance regardless of factors such as fall-history [3] or neurological disorder [29].

Future research should examine how postural control is influenced by more extreme levels of anxiety, how balance confidence can be enhanced and anxiety reduced and how postural strategies may interact with underlying balance problems due to age and disease [4, 29]. Furthermore, future comprehensive treatments might target both physiological and psychological determinants of balance and mobility deficiencies [30].

Key points
- Strong links between balance confidence, anxiety and balance performance in the elderly.
- Increased anxiety is correlated with a stiffening strategy in younger and older adults.
- Need for context-specific measures of physiological status, anxiety and self-efficacy.
- Balance rehabilitation should also focus on physiological and psychological factors.

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References


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