The effects of usual footwear on balance amongst elderly women attending a day hospital

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Abstract

Objective: to examine the effects of footwear on balance in a sample of older women attending a day hospital.
Design: this was a crossover trial with a quasi-randomised allocation.
Setting: assessments took place in the geriatric day hospital.
Subjects: a cohort of 100 older women aged 60 years and over attending a day hospital.
Methods: demographic data and a brief falls history were recorded. Participant's footwear was assessed using a footwear assessment form. A Berg Balance Scale (BBS) was completed under two conditions—shoes on and shoes off with order counter-balanced.
Results: the mean BBS was 39.07 (SD 9.14) with shoes on and 36.54 (SD 10.39) with shoes off (P < 0.0001). Balance scores were significantly higher with shoes on for 10 of the 14 Berg subcategories. Lower barefoot BBS scores were associated with a greater beneficial effect of footwear on balance (P < 0.001). Shoe characteristics were not associated with change in the BBS score.
Conclusions: Wearing their own footwear significantly improved participants' balance compared to being barefoot. The greatest benefit of footwear was seen in those with the poorest balance. Further studies should investigate whether particular types of footwear are associated with greater benefit.

Keywords: elderly, shoes, balance, day hospital

Introduction

Around one in three older people falls each year with one-third of over 65s and half of over 80s falling each year [1]. Some authors have suggested that poorly fitting footwear and slippers or shoes with inadequate fixation may increase the risk of trip-related falls [2–6]. The slip resistance of shoes has not been extensively evaluated although it has been suggested that older people at risk of falls should wear textured slip-resistant soles [2, 7] and some laboratory mechanical tests to simulate heel contact suggest that a bevelled heel may increase slip resistance [8–10].
Wearing inappropriate footwear may also impair balance and alter gait patterns in the elderly [11, 12]. The shoe features which have been shown to influence balance performance include heel height [13, 14], heel collar height [15] and sole thickness and hardness [16].

Heel height and width influence a shoe’s tendency to tip sideways on an uneven surface, as well as influencing gait and posture [13, 14, 17–20]. Lord and Bashford [14] evaluated balance in 30 older women when barefoot, wearing low-heeled walking shoes, wearing high-heeled shoes and wearing their own shoes. The worst balance performance was seen when subjects wore high heels.

High-heel counters have been associated with improved balance [15]. The authors postulated that the heel collar height may be associated with improving proprioceptive feedback of ankle position and movement thereby providing an additional tactile cue and contributing to greater ankle stability.

Contrary to the findings of Robbins et al. [16], Lord et al. [15] found no relationship between sole hardness and balance in 42 older women. However, the results are not directly comparable as the authors used different balance tests (beam walking test versus swaymeter) and different methods to evaluate footwear midsole density.

The sole material and shoe tread design can affect the coefficient of friction on the walking surface, which may influence the risk of slipping [10, 21–23].

Most of the studies to date have been carried out in community dwelling older subjects. The effects of footwear on older subjects at high risk of falls have been less studied. The aim of this study was to examine the effects of usual footwear (versus going barefoot) on balance in frail older women attending a geriatric day hospital.

Methods

Subjects

A convenience sample of 100 older women presenting as outpatients to a geriatric day hospital of an acute general teaching hospital volunteered to participate in the study. They represented the majority of women considered as being at risk of falls after comprehensive geriatric assessment carried out by a consultant geriatrician over a 10-week period. Less than 5% of subjects refused. The inclusion criteria included older women who were 60 years of age or older who were attending the geriatric day hospital, who were able to stand independently and who were able to follow simple instructions. The exclusion criteria included men, and those with an abbreviated mental test score (AMTS) [24] <7, who were non-ambulatory and could not stand independently. All participants were asked to give informed consent and signed a consent form prior to participating in the study. The study was approved by the Hospital Ethics (Medical Research) Committee.

Procedure

Subject characteristics

Information on age, level of mobility, medications, use of glasses and social support was determined. Falls history was also noted and subjects were asked if they had fallen at any time in the past year and if so were asked to indicate the frequency and location.

Footwear assessment

Subjects’ footwear was assessed using the footwear assessment form (FAF) which is a reliable tool for the assessment of shoe style, heel height, fixation, heel counter stiffness, longitudinal sole rigidity, sole flexion point, tread pattern and sole hardness [25] (see Appendix 1, available at Age and Ageing online). For the purposes of this analysis, scores from the right shoe were used.

Balance assessment

The Berg Balance Scale (BBS) was used to assess balance. It is a performance-based measure of balance consisting of 14 tasks, which are directly observed [26]. Each item is scored on a five-point ordinal scale (0–4), which gives a total score ranging from 0 to 56 points with higher scores indicating better balance. In the tasks which required the subject to place the foot on a step or to reach forward, the choice of which leg to stand on was decided by the subjects. The examiner was allowed to demonstrate the task before it was performed by the subject. The reliability and validity of the scale have been established [26, 27]. Balance was assessed under two conditions in this study: shoes on and shoes off. The order of testing with shoes on and off was counterbalanced so that 50% of patients were tested ‘shoes on’ first and 50% ‘shoes off’ first so as to avoid an order effect when testing.

Design

This was a crossover trial with a quasi-randomised allocation.

Standardisation

All of the assessments were taken in the mornings and were administered by an experienced physiotherapist and a student physiotherapist in a quiet, bright physiotherapy treatment room. Subjects were examined carrying out the BBS on two occasions (with ‘shoes on’ or ‘shoes off’) ~5 min apart. Each subject was assessed by the same physiotherapist. The initial subject seen each day by each therapist was randomised to either ‘shoes on first’ or ‘shoes off first’. The second subject was allocated to the opposite order. Subsequent subjects that day were allocated to the opposite order from the preceding subject. The patients were recruited and
assessed between July and September 2005. A pilot study was held in the first week of the study to standardise the Berg and footwear assessments.

Statistical analysis

A standard deviation of BBS score of 3.4 was assumed in this patient population [28] and with an alpha of 5% a sample size of 90 was required to have an 80% power to show a one-point difference in the BBS score. Shoe effects were calculated using a repeated measures analysis of variance with BBS score as the dependent variable and subject, condition (shoe on or off), time (first or second time having BBS test administered) and order (shoes first or shoes off first) as the independent variables. This was performed for both BBS total score and each subcategory score.

Baseline predictors of shoe effect were determined initially using a series of univariate regressions where the difference in the BBS score (on/off) was compared to each factor in turn, and subsequently all baseline factors were used in a multi-variable model. More details about the statistics are available in Appendix 2 (available at Age and Ageing online).

Results

One hundred elderly females were assessed with a mean age of 82 (range 61–95) years. Characteristics are described in Table 1 but most were living in the community, required a mobility aid and had had a fall in the previous year.

The majority of ladies wore a walking style shoe (42%), 17% wore a sandal, 12% a court shoe, 11% a moccasin, 6% a slipper and 12% other footwear.

There was a significant improvement in the mean BBS score [28] and with an alpha of 5% a sample size of 90 was required to have an 80% power to show a one-point difference in the BBS score. Shoe effects were calculated using a repeated measures analysis of variance with BBS score as the dependent variable and subject, condition (shoe on or off), time (first or second time having BBS test administered) and order (shoes first or shoes off first) as the independent variables. This was performed for both BBS total score and each subcategory score.

Baseline predictors of shoe effect were determined initially using a series of univariate regressions where the difference in the BBS score (on/off) was compared to each factor in turn, and subsequently all baseline factors were used in a multi-variable model. More details about the statistics are available in Appendix 2 (available at Age and Ageing online).

Table 1. Demographic characteristics and footwear of subjects

<table>
<thead>
<tr>
<th>Subject characteristics</th>
<th>Range</th>
<th>(n = 100) Mean/ standard deviation (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td></td>
<td>82.0 (6.5) 61–95</td>
</tr>
<tr>
<td>AMTS score</td>
<td></td>
<td>8.2 (1.9) 0–10</td>
</tr>
<tr>
<td>Berg Balance Scale score (shoes on)</td>
<td></td>
<td>39.1 (9.1) 12–53</td>
</tr>
<tr>
<td>Berg Balance Scale score (shoes off)</td>
<td></td>
<td>36.5 (10.3) 7–55</td>
</tr>
<tr>
<td>Percentage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Musculoskeletal medications</td>
<td></td>
<td>24</td>
</tr>
<tr>
<td>Cardiac medications</td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>Psychoactive medications</td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>4+ medications</td>
<td></td>
<td>88</td>
</tr>
<tr>
<td>Use of a mobility aid</td>
<td></td>
<td>68</td>
</tr>
<tr>
<td>Fall in previous year</td>
<td></td>
<td>80</td>
</tr>
<tr>
<td>Number of falls in past year median (range)</td>
<td></td>
<td>1 (0–8)</td>
</tr>
<tr>
<td>Living alone</td>
<td></td>
<td>51</td>
</tr>
<tr>
<td>Living with family</td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>Living in residential or nursing care</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Spectacles</td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>(other than for reading)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walking shoe</td>
<td></td>
<td>42</td>
</tr>
<tr>
<td>Heel height ≤2.5cm</td>
<td></td>
<td>25</td>
</tr>
<tr>
<td>Heel height 2.5–5cm</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>Heel height &gt;5cm</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>No fixation</td>
<td></td>
<td>53</td>
</tr>
<tr>
<td>Unstable heel counter</td>
<td></td>
<td>73</td>
</tr>
<tr>
<td>Sole flexes &gt;45°</td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>Sole flexes before MTPJs</td>
<td></td>
<td>52</td>
</tr>
<tr>
<td>Smooth, partly worn or fully worn sole</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>Soft sole</td>
<td></td>
<td>18</td>
</tr>
</tbody>
</table>

MTPJs, metatarsophalangeal joints.

Table 2. Berg Balance Scale subcategory scores compared to shoes on and off conditions in a repeated measures analysis of variance model

<table>
<thead>
<tr>
<th>Difference in category score (shoes on/shoes off)</th>
<th>Mean</th>
<th>95% CI</th>
<th>F ratio (1, 98 d.f.)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sit–stand</td>
<td>0.15</td>
<td>0.03 to 0.27</td>
<td>5.9</td>
<td>0.018</td>
</tr>
<tr>
<td>Standing unsupported</td>
<td>0.16</td>
<td>0.02 to 0.30</td>
<td>5.3</td>
<td>0.029</td>
</tr>
<tr>
<td>Sitting unsupported</td>
<td>−0.04</td>
<td>−0.09 to 0.01</td>
<td>2.0</td>
<td>0.158</td>
</tr>
<tr>
<td>Standing to sitting</td>
<td>−0.08</td>
<td>−0.01 to 0.17</td>
<td>3.0</td>
<td>0.088</td>
</tr>
<tr>
<td>Transfers</td>
<td>0.03</td>
<td>−0.06 to 0.12</td>
<td>0.2</td>
<td>0.408</td>
</tr>
<tr>
<td>Standing unsupported with eyes closed</td>
<td>0.18</td>
<td>0.03 to 0.33</td>
<td>5.8</td>
<td>0.026</td>
</tr>
<tr>
<td>Standing unsupported with feet together</td>
<td>0.22</td>
<td>0.01 to 0.44</td>
<td>4.2</td>
<td>0.029</td>
</tr>
<tr>
<td>Forward reach</td>
<td>0.16</td>
<td>0.01 to 0.31</td>
<td>4.7</td>
<td>0.034</td>
</tr>
<tr>
<td>Retrieving object from floor</td>
<td>0.07</td>
<td>−0.07 to 0.21</td>
<td>0.9</td>
<td>0.348</td>
</tr>
<tr>
<td>Looking over shoulder</td>
<td>0.22</td>
<td>0.05 to 0.39</td>
<td>6.7</td>
<td>0.013</td>
</tr>
<tr>
<td>Turning 360°</td>
<td>0.25</td>
<td>0.10 to 0.40</td>
<td>11.3</td>
<td>0.001</td>
</tr>
<tr>
<td>Placing alternate foot on step</td>
<td>0.43</td>
<td>0.23 to 0.63</td>
<td>17.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Tandem stand</td>
<td>0.48</td>
<td>0.26 to 0.70</td>
<td>18.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Single-leg stance</td>
<td>0.21</td>
<td>0.05 to 0.37</td>
<td>6.7</td>
<td>0.011</td>
</tr>
</tbody>
</table>

d.f., degrees of freedom; CI, confidence interval.
the lower the barefoot BBS, the greater the effect of wearing shoes on balance.

**Discussion**

This study is the largest to date looking at the effects of footwear on balance in elderly community-dwelling women at high risk of falls. It showed that wearing their own footwear was associated with significantly improved balance compared to being barefoot. The greatest benefit of footwear was seen in subjects with the poorest balance.

The finding of a protective effect of footwear on balance of elderly women is consistent with the work of Robbins *et al.* [16] who found that in a convenience sample of 25 healthy men (aged 60 years and older), being barefoot was associated with significantly more balance failure while walking along a beam. The results differ however from the work of Lord *et al.* [14] who found that in a convenience sample of 30 elderly women (mainly recruited from a hostel for aged persons providing domestic care and with a mean age of 79 years), balance was best when barefoot. However, only eight (27%) subjects used a mobility aid (compared with 68% in our study) and only 10 (33%) reported a fall within the preceding 12 months (compared with 80% in our study) suggesting that balance and mobility was much less impaired than in our sample.

Also the tests of balance they used were different. Taken together, these studies suggest that the relationship between footwear and balance is more complex than previously suspected being affected by patient frailty, barefoot balance and type of balance tested. It is possible that patients with poorer balance have deficits in foot and ankle architecture that are type of balance tested. It is possible that patients with poorer balance have deficits in foot and ankle architecture that are compensated for by footwear, whereas more independent subjects have a reduction in balance due to reduced proprioception while wearing shoes, although this warrants further investigation.

Balance tests are useful only in so far as they help predict future performance and our results are further supported by four recent community studies on falls.

Koepsell *et al.* [29] examined the risk of falls in a Washington state sample of community-dwelling older adults in relation to footwear in fallers and matched controls and found that fall risk was markedly increased when participants were not wearing shoes (odds ratio 10.2). While going barefoot was more common in those who had a gait abnormality and who used a gait aid, the strong association of risk of fall persisted after controlling for these variables.

Larsen *et al.* [30] found that in a Danish community sample (aged 66 and older), using indoor footwear without soles was strongly independently associated with falls in the preceding 24 h (odds ratio 5.5).

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**Table 3.** Comparison of patient and footwear characteristics and shoe effect (i.e. BBS score with shoes on (‘Berg on’) minus BBS score with shoes off (‘Berg off’))

<table>
<thead>
<tr>
<th>Dependent variable is</th>
<th>Berg on − Berg off beta coefficient</th>
<th>95% CI</th>
<th>t ratio</th>
<th>Probability P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking shoe</td>
<td>0.73</td>
<td>−1.19 to 2.65</td>
<td>0.75</td>
<td>0.458</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>−0.23</td>
<td>−2.39 to 1.93</td>
<td>−0.21</td>
<td>0.833</td>
</tr>
<tr>
<td>Heel height</td>
<td>0.33</td>
<td>−1.87 to 2.53</td>
<td>0.30</td>
<td>0.766</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.31</td>
<td>−1.85 to 2.47</td>
<td>0.29</td>
<td>0.772</td>
</tr>
<tr>
<td>Fixation</td>
<td>−1.09</td>
<td>−2.97 to 0.79</td>
<td>−1.13</td>
<td>0.262</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>−0.79</td>
<td>−2.95 to 1.37</td>
<td>−0.73</td>
<td>0.468</td>
</tr>
<tr>
<td>Heel counter stiffness</td>
<td>−0.78</td>
<td>−2.66 to 1.10</td>
<td>−0.81</td>
<td>0.421</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>−0.79</td>
<td>−2.81 to 1.23</td>
<td>−0.77</td>
<td>0.445</td>
</tr>
<tr>
<td>Longitudinal sole rigidity</td>
<td>−0.65</td>
<td>−2.77 to 1.47</td>
<td>−0.61</td>
<td>0.545</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.28</td>
<td>−1.88 to 2.44</td>
<td>0.25</td>
<td>0.802</td>
</tr>
<tr>
<td>Sole flexion point</td>
<td>−1.38</td>
<td>−3.26 to 0.50</td>
<td>−1.44</td>
<td>0.152</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>−1.18</td>
<td>−3.06 to 0.70</td>
<td>−1.23</td>
<td>0.220</td>
</tr>
<tr>
<td>Tread pattern</td>
<td>−2.87</td>
<td>−6.54 to 0.80</td>
<td>−1.53</td>
<td>0.128</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>−0.79</td>
<td>−4.91 to 3.33</td>
<td>−0.38</td>
<td>0.703</td>
</tr>
<tr>
<td>Sole hardness</td>
<td>−0.07</td>
<td>−2.20 to 2.07</td>
<td>−0.061</td>
<td>0.952</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.28</td>
<td>−1.92 to 2.48</td>
<td>0.25</td>
<td>0.804</td>
</tr>
<tr>
<td>Living alone</td>
<td>0.80</td>
<td>−1.08 to 2.68</td>
<td>0.83</td>
<td>0.410</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.05</td>
<td>−2.06 to 2.16</td>
<td>0.048</td>
<td>0.962</td>
</tr>
<tr>
<td>Age</td>
<td>0.12</td>
<td>−0.03 to 0.27</td>
<td>1.66</td>
<td>0.100</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.02</td>
<td>−0.14 to 0.18</td>
<td>0.24</td>
<td>0.811</td>
</tr>
<tr>
<td>AMTS</td>
<td>0.03</td>
<td>−0.50 to 0.56</td>
<td>0.12</td>
<td>0.902</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.21</td>
<td>−0.30 to 0.72</td>
<td>0.82</td>
<td>0.414</td>
</tr>
<tr>
<td>Fall</td>
<td>1.60</td>
<td>−0.75 to 3.95</td>
<td>1.33</td>
<td>0.185</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>0.50</td>
<td>−1.87 to 2.87</td>
<td>0.42</td>
<td>0.678</td>
</tr>
<tr>
<td>Barefoot BBS score</td>
<td>−0.22</td>
<td>−0.30 to −0.14</td>
<td>−5.36</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Adjusteda</td>
<td>−0.22</td>
<td>−0.32 to −0.12</td>
<td>−4.34</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

BBS, Berg Balance Scale; AMTS, abbreviated mental test score; s.e., standard error.

*a*Adjusted for all other factors in a multi-variable model.
Tencer [19] found that in a cohort of 1,371 elderly subjects (60% aged from 70 to 79) followed for 2 years that 24 of 324 fallers reported being barefoot at the time of their fall compared to 4 of 321 controls (odds ratio 6.3 (controls recalled their footwear worn the last time they had engaged in an activity broadly similar to that of the matched fall cases at the time of the fall)).

Recent work by Menz et al. [11] on 176 people (mean age 80.1 years) residing in an Australian retirement village identified going barefoot or wearing socks as an indoor falls risk even after adjusting for other factors (odds ratio 13.7). No association was found between shoe characteristics and change in balance.

While this concurs with two recent large studies of older individuals where falls were determined prospectively [11, 19], it is inconsistent with earlier laboratory studies which found associations between footwear characteristics and balance in older individuals [14–16]. These studies tended to focus on more independent individuals than our sample with all [16] or most [14, 15] individuals being independently mobile and the majority not having fallen in the past year. As such our results are not directly comparable.

Factors that might theoretically affect BBS scores on repeated assessment include a ‘learning effect’ [31] (leading to a better response on the second occasion due to familiarity with the assessment) and a fatigue effect (leading to a poorer response on the second occasion due to muscle fatigue). The finding that BBS scores were on average 1.4 points lower during the second assessment suggests a significant effect of fatigue in these elderly patients and emphasises the importance of balancing the order of intervention in crossover trials such as this. Extending the period before re-assessment so as to allow recovery could be expected to reduce any effects of fatigue also. The duration required for this is unclear, however, and might require significantly lengthening the assessment process or a second assessment visit, both of which could introduce new problems in terms of practicality or bias.

This study has several limitations. No recording of foot, ankle or knee characteristics occurred and only women were studied, so it is unclear why footwear gave a benefit and whether this would also be seen in men. There were also no measures of midsole stiffness or of plantar cutaneous sensation. This may be important given that cutaneous sensation from the sole of the foot plays a major role in the control of balance and the likelihood that stiffer midsoles may interfere with the ability to sense the distribution of pressure on the foot accurately [32].

This study also has several strengths. The use of a clinical population of frail older individuals at high risk of falls (i.e. day hospital attendees) is likely to be more representative of those who fall than previous studies who used volunteers [14–16]. The fact that subjects were measured using their own shoes and that benefits were independent of shoe types makes the results more generalisable. The finding that footwear was associated with benefits across a range of balance subscales further strengthens the case for an association.

In conclusion, it was found that wearing their own shoes, compared to going barefoot, was associated with a significant improvement in balance in older women attending a day hospital and that this effect was independent of the individual characteristics of these shoes. Taking into account the findings of increased falls risk in older individuals who go barefoot, we recommend that older individuals at risk of falls do not go barefoot while walking. Further research is needed to more fully understand the effects of footwear on balance and falls.

Key points

- In a group of older women attending a day hospital, wearing their own footwear was associated with significantly improved balance compared to being barefoot.
- The greatest benefit of footwear was seen in subjects with the poorest balance.
- We recommend that older individuals at risk of falls do not go barefoot while walking.

Acknowledgements

The authors would like to thank all the ladies who attended the day hospital and participated in the study. The research project was supported by a Summer Student Research Project Grant from the Royal College of Surgeons in Ireland.

Conflicts of interest

The authors have no conflicts of interest to declare. All authors contributed to the study concept/design, acquisition of subjects, data analysis, interpretation of data and preparation of the final manuscript and give consent for publication.

Ethical approval

The study was approved by the Beaumont Hospital Ethics (Medical Research) Committee. All patients received an information sheet and signed a consent form.

Supplementary data

Supplementary data mentioned in the text are available at Age and Ageing online.

References


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