Article

Relationship between in-shoe pressure measurements and fear of falling among noncommunity-dwelling elderly: a pilot study

Brabants, Antoine, Tassin, Mederic, Debugne, Gauthier, Richards, James, Kubonova, Eliska and Deschamps, Kevin

Available at http://clok.uclan.ac.uk/25641/


It is advisable to refer to the publisher’s version if you intend to cite from the work.

For more information about UCLan’s research in this area go to http://www.uclan.ac.uk/researchgroups/ and search for <name of research Group>.

For information about Research generally at UCLan please go to http://www.uclan.ac.uk/research/

All outputs in CLoK are protected by Intellectual Property Rights law, including Copyright law. Copyright, IPR and Moral Rights for the works on this site are retained by the individual authors and/or other copyright owners. Terms and conditions for use of this material are defined in the http://clok.uclan.ac.uk/policies/
Relationship between in-shoe pressure measurements and fear of falling among non-community-dwelling elderly: a pilot study

Antoine Brabants MSc1, Mederic Tassin BSc1, Gauthier Debugne MSc1, Jim Richards PhD2, Eliska Kubonova PhD3, Kevin Deschamps PhD1,4,5,6

Abstract

Objectives
To investigate the relationship between fear of falling indicators and pedobarographic variables among non-community-dwelling elderly.

Methods
Twenty-seven volunteers were recruited and assigned to three groups according to their level of fear of falling estimated using the Short FES-I score. The in-shoe foot pressure data were collected while walking 10 meters. The relative peak and mean force in different foot regions, functional gait tasks feature, and center of pressure displacement were measured. A Kruskal-Wallis test was performed to assess the differences between groups.

Results
The anterior-posterior displacement of pressure center was significantly different across the groups during weight acceptance and single limb advancement phases. The different pressure regions showed significant differences in relative mean (p=0.006) and peak forces (p=0.004) in hindfoot. The relative peak force was different for a hallux (p=0.042), a first metatarsal head (p=0.026), and a hindfoot (p=0.038).

Conclusions
In-shoe pressure measurement while walking may be important when assessing the risk and the fear of falling among elderly.

Keywords:
aged; geriatric assessment; foot; fall

ABBREVIATIONS
CoP: Centre of pressure patterns
RoI: Regions of interest
WA: Weight acceptance
SLS: Single limb support
SLA: Single limb advancement
MTH1: First metatarsal head
MTH2-3: Second and third metatarsal head
MTH4-5: Fourth and fifth metatarsal head
M-L: Medial/lateral
A-P: Anterior/posterior
GRF: Ground reaction forces
10-MWT: 10-meter walk test

INTRODUCTION
Annually, every third of community-dwelling elderly experience at least one fall (1). These falls may result in morbidity, a reduced level of independence, a poor quality of life, high levels of anxiety, and increased mortality rates (2). The prevalence of fear of falling has been reported up to 92% in people, who had already experienced falling (3), and from 20% to 55% in people without such an experience (4). The fear of falling may result in activity restrictions, increased risk of falling (5), accidental death (4), physical injuries (4), poor quality of life (6), and reduced social interaction (6).

The Short FES-I has been recommended for research and clinical use due to its good validity and reliability (7). The 7-item version has been considered more feasible than the original 16-item one (8). It has been validated among elderly with cognitive impairment (9) and to assess the risk of falling (10).

Plantar pressure measurements could be used when evaluating a balance during walking. The sensory input from plantar pressure plays an important role in standing balance and postural reflexes (11-13). Postural stability is associated with intrinsic foot muscle properties (14) which are active mainly during the stance phase of gait (15). A hallux plantar flexion strength measured by a peak pressure has been shown to be an independent risk factor for falling (16). Foot pressure analysis allows the assessment of foot placement – a predictive factor for falling (17). This
quantifying approach may help to understand mechanisms involved in a risk and fear of falling (18–20). While some pressure-based measures to assess the risks or fear of falling have been studied, the Short FES-I has not been used for that purpose yet. Only two previous studies have investigated pedobarographic features related to walking and a risk of falling (18,21). While fall occurrence rates are higher among non-community-dwelling compared to community-dwelling populations (1,22), most of previous studies have focused on populations that are different from non-community dwelling elderly.

The objective of this study was to evaluate: pressure in different plantar regions, functional gait tasks, and pressure centering patterns within three groups that differed regarding the severity of fear of falling.

METHODS

The 27 non-community-dwelling elderly were recruited from three nursing homes in Brussels. All the participants were able to walk 10 meters without walking aids and to understand spoken and written French. People with history of stroke, surgery during the past 6 months, or major psychiatric disorders were excluded. All the participants provided written informed consent approved by an institutional medical ethics committee.

The initial part of protocol included the Swiss French version of Short FES-I questionnaire (23). Using the cut-off points suggested by Delbaere et al. (7), three groups were formed based on their level of fear of falling: low (7–8 points), moderately (9–13 points) and high (14–28 points) – here “low group”, “moderate group”, and “high group”. Within seven days all the subjects were given a pair of suitably sized and standardized gender-specific athletic shoes of a particular brand (Artengo TS730) (24) (Figure 1). The qualitative assessment of male and female shoe types was performed using the Footwear Assessment Tool (25) (Table 2). The subjects were asked to wear them for a week until the next experimental session. The participants were excluded if not wearing the given shoes as reported by themselves or by healthcare professionals. After one week, the participants attended a final session and performed a 10-meter-walk test three times at their comfortable walking speed wearing standardized shoes with F-scan® in-shoe pressure measurement insoles (26) (Figure 1). To restrict the effect of acceleration and deceleration on the gait speed calculation, the subjects began walking 1.2 meter before the 10 meters and stopped 1.2 meter after that. Based on the manufacturer manual, the pressure matrices were calibrated for each participant. The plantar pressure measurements were started approximatively one second before starting walking and they were collected for 15 seconds at sampling frequency of 80 Hz. An examiner recorded the time using a digital stopwatch.

Data were processed using F-Scan Mobile Research 5.72® (26) and Microsoft Excel 2016® (27). Initially, three representative stance phases were selected for each walking session yielding nine representative trials per foot. After the vertical ground reaction force for each trial was extracted and normalized to 100% of stance phase and

Table 1: Baseline demographics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Fear of falling</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Mean (SD)</td>
<td>Moderate Mean (SD)</td>
</tr>
<tr>
<td>n</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>Age (SD), years</td>
<td>80.1 (8.6)</td>
<td>80.4 (8.0)</td>
</tr>
<tr>
<td>Height (SD), cm</td>
<td>167 (5.32)</td>
<td>159 (10.4)</td>
</tr>
<tr>
<td>Weight (SD), kg</td>
<td>67.9 (8.7)</td>
<td>68.7 (16.8)</td>
</tr>
<tr>
<td>BMI (SD), kg/m²</td>
<td>24.3 (2.0)</td>
<td>27.0 (4.9)</td>
</tr>
<tr>
<td>10-MWT (SD), sec</td>
<td>15.3 (6.4)</td>
<td>15.8 (9.2)</td>
</tr>
<tr>
<td>Men/women ratio</td>
<td>6/1</td>
<td>4/6</td>
</tr>
</tbody>
</table>

1 Kruskal-Wallis test; 2 Chi-squared test; 3 10-minute walk test
body weight, an average pattern was calculated for each foot. The duration of the three sub-phases of stance phase were determined manually. Weight acceptance (WA) was defined as a phase between initial contact and first peak force. Single limb support (SLS) was defined as a phase between a first and a second peak force. Single limb advancement (SLA) was defined from a second peak and a toe-off (28) (Figure 2). This way, the duration of each phase (%), the total stance time, and the time to reach a first and a second peak force were obtained. In addition, several ROI from the in-shoe pressure recordings were analysed. The ROIs included; the hallux, first metatarsal head (MTH1), second and third metatarsal head (MTH2-3), fourth and fifth metatarsal head (MTH 4-5) and hind foot (Figure 1). For each of the regions, the relative peak force during WA, SLS and SLA, as well as the relative mean force during SLS and SLA were calculated and normalized based on a body weight. Finally, centers of pressure pattern and relative displacements in mediolateral and anteroposterior directions (%) during sub-phases were calculated.

**Statistical analysis**

The Kruskal-Wallis test was performed to determine the differences between groups. To correct for multiple comparisons, the α values were adjusted by a factor of 5 to α =0.01. The data from the right and left sides were well correlated (r>0.5 for 61% of the compared variables) and, therefore, the data obtained from the left side were used in the further analyses.

**Table 2. Shoe assessment based on the Footwear Assessment Tool**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men (42)</th>
<th>Women (42)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age of shoe</td>
<td>0-6 months</td>
<td>0-6 months</td>
</tr>
<tr>
<td>Footwear style</td>
<td>Athletic shoes</td>
<td>Athletic shoes</td>
</tr>
<tr>
<td>Materials (upper)</td>
<td>Synthetic</td>
<td>Synthetic</td>
</tr>
<tr>
<td>Materials outsole</td>
<td>Rubber</td>
<td>Rubber</td>
</tr>
<tr>
<td>Weight</td>
<td>295 g/shoe</td>
<td>274 g/shoe</td>
</tr>
<tr>
<td>Length</td>
<td>28.8 cm</td>
<td>28.8 cm</td>
</tr>
<tr>
<td>Weight/length</td>
<td>10.24</td>
<td>9.51</td>
</tr>
<tr>
<td><strong>General Structure</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heel height (at point of the 1st MTPJs)</td>
<td>2.4 cm (0.0 - 2.5 cm)</td>
<td>2.7 cm (2.6 - 5.0 cm)</td>
</tr>
<tr>
<td>Forefoot height</td>
<td>2.0 cm (1.0 - 2.0 cm)</td>
<td>2.0 cm (1.0 - 2.0 cm)</td>
</tr>
<tr>
<td>Longitudinal profile</td>
<td>0.4 cm: flat (0.0 - 0.9 cm)</td>
<td>0.7 cm: flat (0.0 - 0.9 cm)</td>
</tr>
<tr>
<td>Last (centre goniometer at 50% shoe length)</td>
<td>10°: semi-curved (5° - 15°)</td>
<td>10°: semi-curved (5° - 15°)</td>
</tr>
<tr>
<td>Fixation of upper to sole</td>
<td>Slip-lasted</td>
<td>Slip-lasted</td>
</tr>
<tr>
<td>Forefoot sole flexion point</td>
<td>Proximal to 1st MTPJ</td>
<td>Proximal to 1st MTPJ</td>
</tr>
<tr>
<td><strong>Motion Control Properties Scale</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midsole density layers</td>
<td>Single density</td>
<td>Single density</td>
</tr>
<tr>
<td>Fixation (upper to foot)</td>
<td>Laces</td>
<td>Laces</td>
</tr>
<tr>
<td>Heel counter stiffness</td>
<td>Moderate (&lt;45°)</td>
<td>Moderate (&lt;45°)</td>
</tr>
<tr>
<td>Midfoot sagittal stability</td>
<td>Moderate (&lt;45°)</td>
<td>Moderate (&lt;45°)</td>
</tr>
<tr>
<td>Midfoot torsional stability</td>
<td>Moderate (&lt;45°)</td>
<td>Moderate (&lt;45°)</td>
</tr>
<tr>
<td>Motion control score</td>
<td>6/11</td>
<td>6/11</td>
</tr>
<tr>
<td><strong>Cushioning</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presence</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Lateral Midsole hardness</td>
<td>Hard</td>
<td>Hard</td>
</tr>
<tr>
<td>Medial Midsole hardness</td>
<td>Hard</td>
<td>Hard</td>
</tr>
<tr>
<td>Heel sole hardness (centre of inside heel shoe)</td>
<td>Firm</td>
<td>Firm</td>
</tr>
</tbody>
</table>
RESULTS

Of the participants, 16 were women and 11 were men. The average age was 82.0 (7.4) years, the average height 161.7 (7.7) cm, and the average weight was 74.4 (16.5) kg. Of the 27 participants, 7 belonged to a group with low fear of falling, 10 to a moderate group, and 10 belonged to a group with high fear of falling (Table 1). There were not significant differences between groups in age, height, or self-selected speed. The weight (p=0.014) and body mass index (p=0.001) were significantly higher in a high group comparing to a low group. Additionally, the men/women ratios within groups were significantly different (p=0.0075) (Table 1).

DISCUSSION

The in-shoe pressure measurements demonstrated that WA duration and the anterior-posterior displacement of WA and SLA varied between groups with different severity of fear of falling. There were significant differences in hindfoot centers of pressure regarding relative mean and peak forces during SLA. Relative peak forces during WA were different in hallux, MTH1, and in hindfoot.

While previous studies have mostly focused on the duration of stance phase, the present study was the first one that extended its focus on the relative duration of WA suggesting a relationship between a prolonged double limb support time and a fear of falling among elderly (19,29). It may be speculated that people with higher level of fear of falling may find achieving initial limb stability being more difficult and, thus, they may compensate their impaired balance by needing more time in that sub-phase (28). These time differences may probably also be explained by the differences seen in regional displacements reflecting the lack of stability in WA.

Force measurements in different regions showed differences in relative pressure under MTH1, hallux, and hindfoot with higher estimates observed in a high group compared to a low group. The findings are in line with previous studies highlighting the role of hallux flexor strength measurements (measured as a relative peak force) when evaluating the risk of falling (16). Peak forces in midfoot and lesser toes may also play an important part when evaluating a risk of falling among elderly (16,21).

Previous studies have reported the relationship between gait variability and a risk and fear of falling among elderly (18–20). Most of these studies have investigated a spatiotemporal variability in gait. In addition, a recent study has examined the variability of absolute displacement of center of pressure in mediolateral and anteroposterior directions finding a significant relationship between a risk of falling and fluctuations in that displacements during a pre-swing phase at a defined speed task (18). In the present study, the variability of anteroposterior relative displacement during WA and SLA subphases was associated with a Short FES-I score without such a relationship between a Short FES-I score and mediolateral relative displacement.

The differences between the present results and previous research might lay in differences between community-dwelling and non-community-dwelling populations or in differences that appear when using a force plate (barefoot) versus in-shoe pressure measurements. Diversities in displacement calculation schemes (absolute versus relative), settings (self-selected versus predefined walking speed), or in the measures of risk of falling (history of falls versus Short FES-I) might also explain dissimilar results. The differences between groups might be explicated by a possibility that relative displacements in center of pressure may be influenced by different relative durations of subphases and, thus, may reflect the dissimilarities in foot kinematics.

The study sample was small. The Swiss French version of Short FES-I questionnaire has yet to validated. While the Short FES-I Questionnaire is able to assess the risk and the fear of falling, the cutoffs used in this study were those for the fear of falling and not for the risk of falls. Some demographic differences between groups might influence the results.

Further research may amplify the ability of foot pressure measurements to predict falls. The respective assessment of foot intrinsic muscles may reveal their role in maintaining postural stability.

CONCLUSIONS

In-shoe pressure measurement while walking may be important when assessing the risk and the fear of falling among elderly.
Table 3. Loadings in different regions

<table>
<thead>
<tr>
<th>Relative force (% body weight)</th>
<th>Loadings</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight acceptance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak Hallux</td>
<td>0.33 (0.42)</td>
<td>0.91 (0.67)</td>
</tr>
<tr>
<td>Peak MTH 1</td>
<td>2.27 (0.95)</td>
<td>3.30 (3.15)</td>
</tr>
<tr>
<td>Peak MTH 2-3</td>
<td>3.05 (1.73)</td>
<td>3.64 (3.93)</td>
</tr>
<tr>
<td>Peak MTH 4-5</td>
<td>3.71 (2.22)</td>
<td>3.06 (2.88)</td>
</tr>
<tr>
<td>Mean GRF</td>
<td>61.59 (9.75)</td>
<td>61.38 (15.99)</td>
</tr>
<tr>
<td>Mean Hindfoot</td>
<td>73.84 (6.55)</td>
<td>76.10 (17.24)</td>
</tr>
</tbody>
</table>

Table 4. Functional gait tasks and centers of pressure

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Estimates</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight acceptance</td>
<td>Low group</td>
<td>Moderate group</td>
</tr>
<tr>
<td>Relative duration (% stance duration) of reaching</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st peak force</td>
<td>25.86 (3.48)</td>
<td>27.60 (5.06)</td>
</tr>
<tr>
<td>2nd peak force</td>
<td>79.71 (3.65)</td>
<td>80.20 (3.12)</td>
</tr>
<tr>
<td>WA</td>
<td>25.86 (3.48)</td>
<td>27.60 (5.06)</td>
</tr>
<tr>
<td>SLS</td>
<td>53.86 (4.67)</td>
<td>52.60 (6.07)</td>
</tr>
<tr>
<td>SLA</td>
<td>20.29 (3.65)</td>
<td>19.80 (3.12)</td>
</tr>
<tr>
<td>M-L relative displacement (% total displacement)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>18.63 (10.75)</td>
<td>26.04 (12.52)</td>
</tr>
<tr>
<td>SLS</td>
<td>36.32 (11.93)</td>
<td>34.81 (15.87)</td>
</tr>
<tr>
<td>SLA</td>
<td>43.32 (15.45)</td>
<td>39.15 (15.48)</td>
</tr>
<tr>
<td>A-P relative displacement (% total displacement)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>16.74 (7.71)</td>
<td>21.16 (10.94)</td>
</tr>
<tr>
<td>SLS</td>
<td>72.33 (10.99)</td>
<td>63.85 (13.30)</td>
</tr>
<tr>
<td>SLA</td>
<td>10.93 (5.55)</td>
<td>14.99 (9.13)</td>
</tr>
<tr>
<td>M-L relative displacement mean variability (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>0.32 (0.04)</td>
<td>0.36 (0.18)</td>
</tr>
<tr>
<td>SLS</td>
<td>0.96 (0.36)</td>
<td>1.30 (0.45)</td>
</tr>
<tr>
<td>SLA</td>
<td>0.88 (0.31)</td>
<td>1.03 (0.22)</td>
</tr>
<tr>
<td>A-P relative displacement mean variability (SD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WA</td>
<td>1.18 (0.46)</td>
<td>1.50 (0.83)</td>
</tr>
<tr>
<td>SLS</td>
<td>3.13 (0.97)</td>
<td>3.68 (1.07)</td>
</tr>
<tr>
<td>SLA</td>
<td>0.97 (0.73)</td>
<td>1.02 (0.50)</td>
</tr>
</tbody>
</table>

Kruskal-Wallis test with post-hoc (Tukey-Kramer) correction for multiple comparison – significantly different than the low, moderate, or high group
REFERENCES


ACKNOWLEDGMENTS

None to declare