Standing on textured surfaces: effects on standing balance in healthy older adults

Anna Lucy Hatton1, John Dixon2, Keith Rome3, Denis Martin2

1Centre for Health, Sport and Rehabilitation Sciences Research, University of Salford, Manchester, UK
2Health and Social Care Institute, Teesside University, Middlesbrough, UK
3Division of Rehabilitation and Occupation Studies, AUT University, Auckland, New Zealand

Address correspondence to: A. L. Hatton. Tel: +44 (0)161 295 2049; Email: a.l.hatton@salford.ac.uk

Abstract

Background: standing on textured surfaces or wearing textured shoe insoles can alter balance performance. This evidence, although inconclusive, offers a potential intervention for improving balance in older adults. This study explored the effect of standing on textured surfaces on double-limb balance in older adults and changes in muscle activity as a possible mechanism of effect.

Methods: 50 healthy older adults (29 female, age mean [SD] 75.1 [5.0]) stood quietly in six conditions—eyes open and closed on two different textured surfaces and a smooth surface control. Mediolateral sway, anterior-posterior sway and centre of pressure velocity were extracted from a force platform and lower limb muscle activity collected using surface electromyography (EMG) over 30 s.

Results: for mediolateral range with eyes closed, there was a statistically significant effect of texture (F [2, 47] = 3.840, P = 0.033). This was attributed to a 9.2% decrease with Texture 1 compared with Control. No such effects were seen in any other balance variable or lower limb EMG activity for either visual condition.

Conclusion: the results suggest an effect of standing on textured surfaces on mediolateral sway in older adults, supporting further work to develop the therapeutic benefits of textured surfaces as an intervention to improve balance.

Keywords: textured surfaces, balance, muscle activity, older adults
Introduction

Some people experience a deterioration in balance performance with increasing age, heightening their risk of falling [1]. Mediolateral (ML) balance may be particularly affected [2–5]. Evidence that textured floor surfaces [6] and textured shoe insoles [7–8] can improve static and dynamic balance in healthy young adults points to their potential to improve balance in older people. However, to date only one study has focused on older people, concluding that standing balance improved after wearing textured shoe insoles for 5 min [7]. A textured surface, whether used as a footwear intervention or floor covering, may have the capacity to ameliorate age-related declines in balance by adding sensory input at the feet [7]. Changes in touch sensation and proprioception at the foot are commonly associated with poor balance include changes in muscle activity [11, 12].

Putative mechanisms for the effects of texture on balance include changes in muscle activity [11, 12]. Wearing textured shoe insoles has shown to significantly reduce mean electromyography (EMG) activity in tibialis anterior and soleus in healthy young adults [11] and increase gastrocnemius activity in adults with multiple sclerosis [12] during walking. It is unknown whether texture affects lower limb muscle activity in older adults during standing balance.

An early investigation compared different textured surfaces and showed that an important factor in affecting balance was the density of the protrusions that comprised the texture [6]. However, subsequent studies have explored the effect of only one design of textured intervention compared with control [7, 8, 11, 12] and the importance of texture type remains very much unexplored.

The aims of this study were to explore: (i) the effect of textured surfaces on standing double-limb balance in older people; (ii) the importance of texture type and (iii) the effect of texture on lower limb muscle activity during standing double-limb balance. In this study double-limb balance describes the dynamics of body posture, which occur in response to inertial forces acting on the body, in order to achieve equilibrium between the body and the surrounding environment and prevent falling, when standing on two feet.

Methods

Participants

Independently mobile older men and women aged ≥70 years were recruited in response to advertising, presentations to community groups and personal contact. Exclusion criteria were self-reported neuromuscular disease, stroke, peripheral sensory neuropathy, inner ear problems or inability to walk 10 m unassisted; and a score of <27 on the Mini-Mental State Examination (MMSE) [13–15] and inability to feel a monofilament at ≥4 sites on each foot [16]. All participants gave written, informed consent.

Ethical approval was granted by the School of Health & Social Care Research Governance and Ethics Committee at Teesside University.

Design

In a within-subject experimental design, all participants were tested in a university laboratory under each of six conditions—Control eyes open, Control eyes closed, Texture 1 eyes open, Texture 1 eyes closed, Texture 2 eyes open and Texture 2 eyes closed. The primary outcome was ML balance measured as ML range (mm) and mediolateral standard deviation (ML SD). Other sway variables were anterior-posterior (AP) range, anterior-posterior standard deviation (AP SD) and centre of pressure (CoP) velocity (mm.s⁻¹). For muscle activity, the dependent variable was the average rectified value of EMG activity.

Materials

Two different textured surfaces, and one smooth surface as control, were used (Algeos UK Ltd., Liverpool, UK) (Figure 1). Texture 1 (Evalite Pyramid EVA, 3 mm thickness, shore value A50, black, OG1549) and Texture 2 (nora® Lunasoft Mini Non Slip, 3 mm thickness, shore value A50, black, OG2250) were selected from a range of EVA soling materials [17, 18]. Texture 1 had small, pyramidal peaks with centre-to-centre distances of approximately 2.5 mm. Texture 2 had convex circular patterning with centre-to-centre distances of approximately 5 mm. The Control surface (Medium Density EVA, 3 mm thickness, shore value A50, black, OG1304) had a completely flat surface with no indentations. These surfaces were 428 mm × 630 mm × 3 mm, in order to cover the top surface of a force platform.

Double-limb balance

Data were obtained from one Kistler force platform (Model 9286AA, Kistler, Alton, UK), and sampled at a rate of 1,000 Hz.

Electromyography

EMG recordings were collected using a 16-channel Biopac system (Model MP100), using bipolar active surface electrodes (Type TSD 150B, 11.4 mm diameter, electrode spacing 20 mm), with 3 dB 12–500 Hz bandpass and ×350 built-in amplification, and sampled at 1,000 Hz. After cleaning and shaving the skin, EMG recordings were collected from standardised sites on five muscles: rectus femoris, vastus lateralis, biceps femoris, tibialis anterior and medial gastrocnemius. The dominant leg (‘with which leg would you kick a football?’) was used for testing [19, 20] and a ground reference electrode (Blue Sensor®) was placed at the tibial tuberosity on the non-dominant lower limb.
Procedures

Each participant had a practice trial on the control surface, standing quietly with eyes open for 30 s to ensure familiarity with the procedures. Then, the participant conducted one trial [21, 22] for each of the three different surfaces with eyes open and one trial for each surface with eyes closed—a total of six trials. (One trial per condition was used because of the potential onset of fatigue.) The sequence of trials was fully randomised using number cards selected from opaque envelopes by the participant. To begin each trial the participant stood up from a chair. Once the participant’s trunk and lower limbs were vertical, the investigator pressed a trigger which started data collection simultaneously from the Kistler force platform and EMG system, for 30 s. Between each trial, participants rested for 2 min to avoid fatigue and habituation to the sensory stimulus, and to allow re-calibration of the force platform. All data collection was carried out by the same investigator (ALH). Neither the investigator nor the participants were blind to the condition being tested.

Data extraction and analysis

ML and AP variables were calculated automatically by the force platform for 30 s in each trial, using the Bioware software package. CoP velocity was calculated using previous methods [2], after low-pass filtering of the raw data at 10 Hz. The first 10 s of sway data may be highly variable due to stabilisation of participants [23] or the force platform [2], so were discarded from the analysis [2, 18]. EMG data were processed using dedicated AcqKnowledge software (Version 3.7.3, BIOPAC Systems, Inc., Santa Barbara, CA, USA). After processing with a 20 Hz high-pass filter and a root mean square moving window of 30 ms, the average rectified value EMG was extracted for each muscle.

Statistical analysis

Data were analysed with SPSS (Chicago, IL, USA) version 13.0. For each variable, a repeated measures analysis of variance (ANOVA) was conducted to determine effects of texture. Separate ANOVAs were carried out for the conditions of eyes open and eyes closed. Alpha was 0.05. Where the assumption of sphericity was violated, a Greenhouse–Geisser correction was applied. Comparisons between each pair of textured conditions were obtained from the main ANOVAs.

Results

Fifty participants (29 women) were recruited with a mean (1SD) age 75.1 (5.0) years; height 164.0 (7.9) cm; weight 72.2 (10.9) kg; BMI 26.9 (4.0) kg/m²; MMSE 28.7 (0.9). All participants completed the study.

Postural sway

Tables 1 and 2 show the results with eyes closed and open, respectively. There was a statistically significant effect of texture for ML range with eyes closed ($F[2, 47] = 3.840$, $P = 0.033$). The paired comparison between Control and Texture 1 showed a significant reduction in ML range of 9.2% by Texture 1. There were no statistically significant effects of texture for ML SD, AP sway, or CoP velocity.

There were no statistically significant effects of texture for any of the variables with eyes open. Inspection of the 95% CIs for differences between pairs of textured conditions supports that. All contain zero well within the interval.

Electromyography

Tables in, Supplementary data available in Age and Ageing online, Appendixes 1 and 2 show the results for EMG activity with eyes open and eyes closed. There were no statistically significant effects of texture on muscle activity for any of the conditions.

Discussion

This study provides evidence that textured surfaces can improve ML sway in older people. A statistically significant
The effect on ML sway is important because that direction of sway dependent on the area of added indentation of varying density and height which meant the surfaces were probably in fuller contact with a greater surface of the sole of the foot than ours. This is of note because it has been suggested that total and even stimulation of the sole is important for stimulation of mechanoreceptors by textured surfaces [6]. Also, Meyer et al. [24] reported that experimental reduction in sensation of the sole of the forefoot resulted in poorer ML balance, whereas anaesthesia of the whole sole caused poorer AP balance. This finding of selective effects on the direction of sway dependent on the area of anaesthesia may translate into selective effects on the direction of sway dependent on the area of added sensory stimulation: as neither study measured the degree of contact with the sole such ideas are hypothetical.

The finding of effects with Texture 1 but not Texture 2 agrees with the findings of Watanabe and Okubo [6] that the type of texture can be important although the textures in that study were quite different to those in ours. The physical characteristics of indenting protrusions, including shape, thickness, density, spacing or contouring effects, may have implications on the degree of deformation of the plantar skin and thus stimulation of mechanoreceptors.

There were no statistically significant effects of texture with eyes open. It is possible that balance was
sufficiently good with eyes open, so that there was little scope for the Texture 1 to add to performance. However, removal of the visual system (eyes closed) may have left sufficient space for effects of Texture 1 to become apparent. Indeed, in ML range the effect size of the difference between Control eyes closed and Texture 1 eyes closed (0.373) is relatively similar to the effect size of the difference between Control eyes closed and Control eyes open (0.288). This suggests that the effect of Texture 1 was relatively similar to opening the eyes, an observation that has been previously reported, though not with the same textures as we used [8].

The lack of effects on muscle activity suggests that this was not involved in the change in ML sway seen with Texture 1. However, changes in EMG activity may have occurred in other muscles that are involved in ML balance control, but not investigated in this study, such as the lumbarics, interossei, peroneal or gluteal muscles. We limited the number of muscles to prevent lengthy testing that may have been tiring and made our choice based on muscles we had investigated in similar work [17].

There are limitations to the current study. We investigated the effect of textured surfaces rather than shoe insoles. This was to prevent confounding effects of footwear including shoe construction, heel height, insole contouring and fastening mechanisms. The effect of textured surfaces on balance performance was assessed during double-limb quiet standing. This is a substantial test for determining the effects of sensory manipulation on balance [2, 8, 25] and provides justification for further work using more complex tests of balance. Only one trial was conducted per condition due to the potential onset of fatigue with more extensive test procedures. Although conducting more trials per condition may have reduced measurement error or noise, we did not want to risk fatigue as a confounder or distress participants. Our study sampled from a population of healthy older adults and care should be taken in generalising outwith that to populations that were excluded—specifically, older people with peripheral sensory problems, balance impairments or other falls risk factors.

Conclusions

The study provides evidence that textured surfaces can improve ML balance performance in healthy older people, and shows that this depends on the type of texture. Further work is required on three broad areas. It is necessary to test the effects on a population of older people prone to falling. Investigation is also required using a larger range of different textures to see if some types are more effective in enhancing postural stability, as is indicated here. Finally, investigation is required on more complex dynamic measures of balance such as sit-to-stand, walking and dual tasking.

Key points

- Standing on textured surfaces can affect ML sway in healthy older people.
- The presence of effect only with eyes closed suggests that texture may provide a surrogate source of sensory information for balance control when one or more of the remaining sub-sensory systems are redundant.
- There may be an optimal textured pattern, in terms of the geometric shape and distribution of indenting protrusions.
- There was no evidence of accompanying changes in muscle activation.

Funding

This work was supported by a British Geriatrics Society/ Dunhill Medical Trust Fellowship. The study sponsors had no involvement in the study design, analysis, interpretation of data, writing or submission of this manuscript.

Supplementary data

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

References