SLIPPERS, SURFACES AND THE GAIT OF OLDER ARTHRITIC FEMALES: THE FINAL EPISODE?

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INTRODUCTION

Falls are the leading cause of unintentional injury, death and disability in persons aged 65 years and above. Most falls sustained by older people who are living independently in the community occur inside their own home, usually resulting from slips, trips, or losses of balance (Campbell *et al.*, 1990). However, one of the most frequent precipitating events leading to a person falling and becoming injured is a loss of traction between their footwear and the supporting surface at initial foot-ground contact. Typically, environmental factors such as smooth, shiny or slippery floors, particularly when integrated with inappropriate household footwear, can lead to this loss of traction and have therefore been identified as major contributors to home falls (Hourihan *et al.*, 2000).

One population known to have foot pain and significant deformities resulting in abnormal weight bearing, gait disturbance, and footwear difficulties, is that of older women with rheumatoid arthritis (RA; Woodburn & Helliwell, 1996). As a result, slippers are often the preferred household footwear choice for this population, as they lack structure and can mould to the shape of any foot (Marr, 1993). However, slippers tend to become 'sloppy" and can provide an insecure base for gait, in turn, creating the potential for the wearer to fall, and are therefore usually discouraged (Marr, 1993). For example, in a study of 107 predominantly female individuals (mean age = 77 years) who had been admitted to hospital after fracturing their neck of femur it was found that in over 30% of cases slippers were worn at the time of the fall (Hourihan *et al.*, 2000). The authors of this study also reported that most of these falls occurred on carpet, reflecting the higher proportion of carpet as a household surface. However, 20% of falls occurred on tiled and linoleum surfaces whereby the injuries incurred on these less compliant surfaces were often more severe than those incurred on carpet (Hourihan *et al.*, 2000). Although, the typical household surface in older peoples' homes is carpet, areas such as the kitchen, laundry, and bathroom are usually covered with waterproof surfaces such as tiles or linoleum. Despite their functionality, water spillage on such surfaces can result in areas of low friction and, in turn, the potential for slips associated with loss of traction. Consequently, it is recommended that older people cover the floors of their homes with non-slip surfaces that interact well with commonly worn household footwear types (Hourihan *et al.*, 2000). Despite these claims with respect to household footwear and surfaces, little is known about how either affect the gait of older people, particularly those suffering RA, or how wearing slippers on typical household surfaces may increase the risk of slipping in older people. Therefore, the purpose of the present study was to determine how variations in slipper and surface type affected the gait of older RA women, specifically the muscular activation patterns displayed by these women when preparing for initial foot-ground contact.

METHODS

Eight older RA women (67.8 ± 7.3 years) and eight unaffected women (65.3 ± 3.1 years) matched to the RA subjects for age, height and mass participated in the study. While wearing a custom-designed safety harness system, the subjects walked along an 8 m carpeted walkway, contacting a force platform embedded midway, at a self-selected speed under three footwear conditions (barefoot, toe slippers, closed-back slippers) and three surface conditions (carpet, dry linoleum, wet linoleum). During the five trials per condition, ground reaction force data and EMG data for seven muscles of each subject's dominant lower limb (gastrocnemius (G), peroneus longus (PL); tibialis anterior (TA); semimembranosus (S); biceps femoris (BF); vastus lateralis (VL); and rectus femoris (RF)) were sampled (1000 Hz) using a Kistler force platform and a Noraxon Telemyo system (bandwidth 0-340 Hz), respectively. Raw EMG signals were full wave rectified and filtered (f_c = 15 Hz) to obtain linear envelopes, to which a threshold detector (7%) was applied to determine the temporal characteristics of each muscle burst (Munro & Steele, 2000). Each muscle burst immediately before initial foot-ground contact was then integrated over its duration to give an indication of muscle intensity (IEMG, V·ms). Onset of the resultant ground reaction force data were used to provide a temporal reference of initial foot-ground contact during gait. Data were then analysed using a three-way ANOVA with one between factor (subject group) and two within factors (footwear and surface type) to determine whether interactions between the footwear and surface conditions had any significant ($p \leq 0.05$) effect on the muscle activation patterns used by the subjects to prepare for initial foot-ground contact.

RESULTS AND DISCUSSION

When the data were pooled across footwear and surface type conditions, there was no significant main effect of subject group on any of the dependent variables. However, there was a significant group x footwear interaction, such that when subject group was moderated by slipper type, RA subjects displayed a significantly earlier VL muscle burst offset, leading to a significantly shorter VL muscle burst duration when wearing both slipper types compared to when walking barefoot. Furthermore, RA subjects displayed significantly less VL muscle burst intensity when wearing both slipper types compared to when walking barefoot. Interestingly, although both subject groups used similar muscle activation patterns, the RA subjects significantly altered their muscle recruitment strategies when walking in the two slipper types compared to when they walked barefoot.

When the data were pooled across subject group and surface type conditions, there were several significant main effects of footwear, such that when walking in toe slippers, subjects activated PL and TA significantly earlier compared to when barefoot or when walking in closed-back slippers. This earlier activation resulted in a significantly longer PL burst duration, accompanied by a significantly longer BF duration, and increased TA muscle intensity all while the subjects wore the toe slippers relative to the other two footwear conditions. It would therefore appear that older women, irrespective of their RA status, require an altered motor control strategy, predominantly from the leg muscles, to try to keep the backless shoe on their foot when walking. The increased effort associated with this greater muscle intensity, earlier onset and longer muscle burst duration while wearing toe slippers may, in turn, lead to fatigue in the muscles directly responsible for lower limb stability during gait, possibly predisposing these women to slips and falls.

When the data were pooled across subject group and footwear type conditions, there were several significant main effects of surface type. For example, RF muscle burst offset occurred significantly later when subjects walked on wet linoleum, resulting in a significantly longer RF muscle burst duration, compared to when walking on carpet or dry linoleum. Subjects also displayed greater RF and S muscle intensity when walking on wet linoleum compared to when walking on either carpet or dry linoleum. In contrast, the subjects displayed a significantly shorter VL muscle burst duration when they walked on dry linoleum compared to carpet or wet linoleum and significantly greater PL muscle intensity when walking on carpet compared to dry or wet linoleum. Although appearing to be somewhat disparate, these main effects of surface were significantly moderated by footwear condition whereby there were significant footwear x surface interactions for five of the dependent variables. The significant footwear x surface interactions for RF muscle burst onset, duration and muscle burst intensity are depicted in Figure 1. Significant footwear x surface interactions were also found for S and VL muscle burst intensity, which showed the same pattern as depicted in Figure 1(C). Post-hoc analyses confirmed that the muscular recruitment strategies used by the women when walking barefoot on the wet linoleum, irrespective of their RA status, differed significantly compared to when they walked across the different surfaces wearing slippers. It could be speculated that the decreased muscular effort displayed by the women when walking on the wet linoleum wearing slippers was due to an increase in friction between the rubber sole of the slipper and the wet linoleum surface. Alternatively, it could be postulated that by walking barefoot, the women were better able to sense the slippery nature of the surface, via uncompromised plantar sensitivity, to adapt their gait to the situation. That is, they displayed a more tentative gait pattern, which may in fact be beneficial in terms of decreasing their slip risk. A significant decrease in the peak anteroposterior ground reaction forces generated during the early stance phase of gait in this barefoot/wet linoleum condition combined with significantly slower gait velocity appears to support this latter notion.

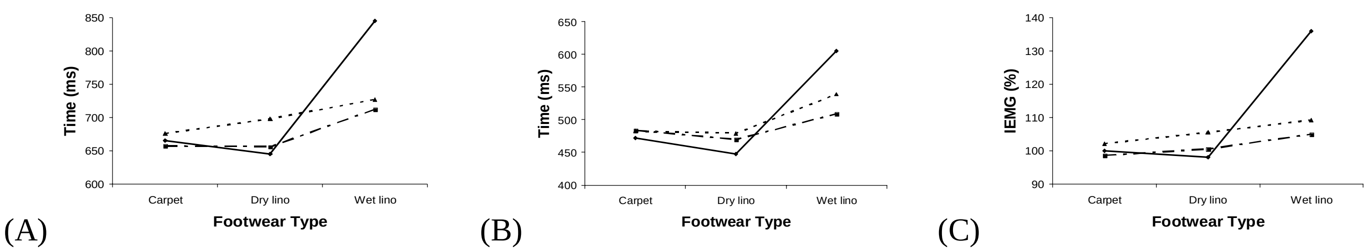

Figure 1. Significant footwear x surface interactions for RF (A) muscle burst offset, (B) duration and (C) IEMG.
(barefoot = ▬; toe slipper = ······; closed back slipper = ─ ─)

SUMMARY

The lower limb muscles are typically recruited in a pre-programmed way to stabilise and decelerate the lower limb to prepare for safe foot-ground contact. In the present study, all women, irrespective of RA status, recruited their lower limb muscles in a similar manner in response to variations in the shoes they wore and the surfaces traversed. That is, when wearing toe slippers all women displayed greater muscular effort to keep these backless slippers on their feet when walking, irrespective of surface type. This increased muscular effort, may place older women, particularly those who are weaker, at a greater risk of falls relative to walking in slippers that enclose the whole foot. As such, toe slippers are not recommended for older women. Similar to the footwear effects, changing the nature of the surface led to altered muscle activation patterns. More importantly, these changes to their pre-programmed muscle recruitment strategies were most evident when the women walked barefoot on a surface they deemed as slippery. These adaptations were possibly reflective of a more tentative gait pattern, developed by these women from previous experience, to decrease their risk of slipping. This ability to adapt their gait patterns to match the environmental conditions may be negated by wearing slippers as they occlude vital plantar sensory information.

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