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Effect of footwear on minimum foot clearance, heel slippage and spatiotemporal measures of gait in older women

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ABSTRACT

Footwear has been implicated as a factor in falls, which is a major issue affecting the health of older adults. This study investigated the effect of footwear with dorsal fixation, slippers and bare feet on minimum foot clearance, heel slippage and spatiotemporal variables of gait in community dwelling older women. Thirty women participated (mean age (SD) 69.1 (5.1) years) in a gait assessment using the GaitRITE and Vicon 612 motion analysis system. Conditions included footwear with dorsal fixation, slippers or bare feet. Footwear with dorsal fixation resulted in improved minimum foot clearance compared to the slippers and bare feet conditions and less heel slippage than slippers and an increase in double support. These features lend weight to the argument that older women should be supported to make footwear choices with optimal fitting features including dorsal fixation. Recommendations of particular styles and features of footwear may assist during falls prevention education to reduce the incidence of foot trips and falls.

1. Introduction

Falls are a major health issue and burden on the public health system. A significant number of reported falls in the older population are related to tripping, which have been attributed to inadequate foot clearance during the swing phase of gait [1]. Footwear has also been identified as playing an important role in the prevention of falls in older adults [2]. Yet older women are reluctant to make changes into footwear that have established fit and features associated with increased stability [3].

Footwear encompassed many different styles, heel heights and features. The features thought to increase the stability of footwear are; dorsal fixation (laces, velcro straps) however there is limited evidence to support this theory. There is an evidence deficit in how dorsal fixation may impact falls yet it is a common recommendation in falls prevention education. Heel height [4,5] has been the primary shoe feature linked with falls in the older. Walking barefoot, in slippers or socks has been correlated with a higher likelihood of falls (odds ratio 13.7) [6] yet many older adults, women in particular, wear slippers in their home [7]. In addition, slippers were the most commonly worn footwear at the time of a fall-related hip fracture in a study of 95 older people [2] and while 16 of these people also were wearing walking shoes, 12 of these people were also in footwear with at least one theoretically sub-optimal feature such as lack of dorsal fixation and flexible heel counter. Whether the fall was initiated by footwear related trip however was not recorded.

Slippers often lack many key features that secure the shoe to the foot and reduce trips and slips. Poor fit (too long or too wide) have been noted as common in rehabilitation settings [8] and retirement villages [9] with older people, primarily for comfort and to accommodate foot deformities. Many slippers do not contain dorsal fixtures or have any form of stabilisation around the heel or sole area. These key structural footwear features may help

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prevent the foot from slipping and may reduce the risk of falls [8–10]. It has not been previously reported in the literature if the fit of the slipper is a contributing factor to falls and how this may compare to dorsally secured footwear.

Inadequate foot clearance during gait may also predispose a person to tripping and falling. Older men have demonstrated variable foot clearance [11] and this variability has been directly related to aging and trips [12]. While these studies have been conducted primarily within bare feet or in a shoe with dorsal fixtures, there has been no established impact of wearing slippers on minimum foot clearance, particularly in older women. Similarly, it is unknown what impact wearing slippers have on the spatiotemporal features of gait (i.e. cadence, time in double support, step length).

Due to the lack of evidence supporting any of the key features in commonly worn footwear impacting on falls, the aim of this study was to examine the effect of footwear on heel slippage (movement of the heel upwards and out of the shoe) and minimum foot clearance during level-ground walking. It was hypothesised that walking in well-fitted footwear with dorsal fixation would result in less heel slippage and a higher minimum foot clearance compared to walking in slippers. A secondary aim of this study was to compare spatiotemporal characteristics of gait when wearing slippers, well-fitted footwear and walking bare foot. It was hypothesised that participants would walk faster, with an increase step length and reduced double limb support in well-fitted footwear compared to walking in slippers or bare feet. This knowledge will improve understanding of the key features of commonly worn footwear and its potential impact on the mechanics of falls.

2. Method

2.1. Study design

This study designed was a within subject randomised control trial for the three footwear conditions. Permuted block randomisation between footwear conditions was conducted.

2.2. Participants and setting

Thirty community dwelling females aged between 60 and 80 years were recruited to participate in the study. Power estimates were calculated from the effects of footwear on walking speed and confirmed that 30 participants would provide sufficient statistical power ($\alpha = .05, 1; \beta > .8$) for this study [13]. Inclusion criteria required that participants were able to ambulate unaided, have no cardiothoracic, orthopaedic or neurological symptoms, or medication that had potential to affect their gait and no history of injurious falls. Participants were also excluded if they were diagnosed with severe dysphasia that interfered with communication; or if they presented with significant cognitive impairment affecting their gait or ability to participate in testing.

2.3. Footwear

The primary investigator fitted the "prescribed" footwear and slippers based on the size that the participant usually wore and by ensuring length of 1–2 cm from the longest toe, and minimal medial and lateral movement within the shoe. The "prescribed" footwear was chosen based the common features of footwear articulated within falls prevention management [3]. Slippers choice was made by observing the most common accessible, cost effective slipper in local stores at the time of data collection. Participants were asked if they were comfortable in the shoe and if the shoe felt that it was appropriately fitted to ensure correct fitting. The size of the shoe was recorded within the demographic data.

Participants were fitted with both the:

1. Slippers (Fig. 1a): Synthetic material upper, flat rubber sole, no dorsal fixation, weight, 127 g.
2. Prescribed footwear (Fig. 1b): Low heeled (2.5 cm heel height and 2.0 cm toe pitch), leather upper, laced fixations with five eyelet points, EVA midsole and rubber outsole, 128 g.

Participants were required to wear both the slipper and the prescribed footwear for approximately 2 weeks as part of their normal daily activity, to familiarize themselves with the footwear. Following this, the participants attended a single appointment for three-dimensional gait assessment. At this appointment, demographic data was collected including: age, height and weight.

2.4. Gait assessment

Participants walked five times along a 10 m walkway at their preferred pace for each condition: bare feet; well-fitted footwear; and slippers. For all conditions the participants were requested to look straight ahead and started their walk at least 2 m before an 8.3 m instrumented walkway (GaitRITE®, CIR Systems Inc, Havertown, PA, USA) walkway and were asked to continue walking at least 2 m beyond the end of the walkway to avoid accelerating or slowing down during data capture on the mat. Participants were required to rest between each change in footwear for 5 m to minimise fatigue. Minimum foot clearance and heel slippage were determined using the Vicon 612 motion analysis system sampling at 100 Hz (Vicon Peak, Oxford, UK). Spatiotemporal gait characteristics were calculated from data collected using the instrumented GaitRITE® walkway.

2.5. Minimum foot clearance

Minimum foot clearance was defined as the minimum distance between the plantar, distal aspect of the phalanx and the ground during the mid-swing phase of gait [14]. This measure (mm) was determined by placement of ten reflective markers attached to

Fig. 1. Footwear used within the study: Panel (A) slipper; Panel (B) well-fitted footwear.