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Identifying the Number of Steps Required for Familiarisation to Athletic Footwear in Healthy Older Adults

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Short Title: Footwear Familiarisation in Older Adults

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Keywords: Gait, older adults, footwear familiarisation, footwear, midsole thickness.

Abstract

Introduction: Research on athletic footwear familiarisation within an older population is sparse. This is problematic because unfamiliar footwear may act as a new perturbation and modify older adults' walking gait and stability. In addition, while athletic footwear has been suggested to enhance older adults' comfort and support during activities of daily living, the necessary period for familiarisation with athletic footwear is unknown. Therefore, this study aimed to identify the number of steps required for older adults to be familiarised with athletic footwear of different midsole thicknesses. ***Methods:*** Twenty-six healthy and physically active community-dwelling older adults, 21 females (71.1 ± 4.5 years; 164.5 ± 5.3 cm; 68.4 ± 11.4 kg) and five males (70.6 ± 2.3 years; 175.2 ± 7.8 cm; 72.8 ± 9.7 kg) completed a walking-based protocol. Participants walked two trials of 200 steps at their habitual speed on a 10 m track of an optical measurement system in three footwear conditions: 1) New Balance® REVlite 890v6 (thick midsole); 2) New Balance® REVlite 1400v5 (moderate midsole); and 3) New Balance® Minimus 20v7 (thin midsole). Gait speed ($m.s^{-1}$) and walking time (min) were analysed for each participant over the 400 steps. Number of required familiarisation steps were established over three analysis phases, consisting of steady state gait assessment, averaging and analysis of blocks of 40 steps, and sequentially comparing these steps with a pre-determined threshold. Footwear familiarisation was assumed when the mean gait speed fell within an acceptable level (± 2 SD from 320 to 360 step values) and subsequently maintained. ***Results:*** Most participants were familiarised with all three footwear conditions (thick *n*= 18; moderate and thin *n*= 20) after walking 80 steps. For all participants, the moderate midsole had the shortest familiarisation period (160 steps). The highest number of familiarisation steps were found in the thick (320 steps) and thin midsoles (240 steps) for some participants. ***Conclusion:*** A minimum of 320 familiarisation steps is recommended to account for both individual differences and midsole thicknesses. Implementing this walking-based footwear familiarisation protocol would improve validity of future studies, ensuring they analyse footwear effects rather than familiarisation with the footwear.

Introduction

Athletic footwear has been recommended to improve older adults' comfort and support during activities of daily living [1,2]. However, the necessary period for footwear familiarisation in older adults is poorly recognised. Familiarisation is defined as a short-term adaptation in which variance in repeated measures for a particular variable stabilises to an acceptable level within one session [3]. This process is particularly pertinent when analysing footwear effects [4,5]. However, previous studies investigating the effects of footwear on older adults' postural stability and gait failed to report their familiarisation protocol [6, 7, 8], provided insufficient information for method replication [9], or used protocols that lead to uncertainties whether the familiarisation was for the study procedures or for the footwear [10, 11, 12, 13]. This is problematic because, more than the style of footwear, the lack of familiarisation with a particular type of footwear has been suggested to be a more substantial contributor to fall risk [4], as footwear has been indicated as an extrinsic risk factor associated with falls in this population [14]. Sensory information from plantar cutaneous afferents and foot muscles induces intrinsic automatic postural adjustments in response to new stimuli [15]. Unfamiliar footwear may thus act as a perturbation to older adults' static and dynamic postural stability, and lead to potential alterations in the lower limb biomechanics [16], such as walking gait changes [8, 17], which in turn may increase fall risk. As such, footwear familiarisation is essential before any experimental testing to allow the participants to become acquainted with unfamiliar shoes [5]. Only then, will the results reflect the shoe effects, as opposed to data that may reflect intrinsic postural changes associated with being unaccustomed to a particular type of footwear [5].

Research on athletic footwear typically uses a treadmill for individuals to walk or run to become familiarised with unfamiliar shoes [18, 19]. This is because this equipment allows the capture of repetitive gait cycles in a controlled environment, whereby loading and locomotion patterns can be analysed [20]. Once a stable and consistent pattern is observed in the treadmill locomotion, which is preceded by a change in the variable of interest, familiarisation is assumed [18]. Treadmills may however not be the best choice for footwear familiarisation with older adults. Compared with overground walking, treadmill use has been shown to reduce older adults' gait speed and increase the double support phase time [21], possibly because older adults feel unstable while walking on a treadmill due to being an unfamiliar ergometer for this population. Indeed, previous research reported that older adults tend to use the treadmill handrail to feel secure [22]. In addition, walking on a treadmill may influence older adults' stepping and postural responses [23], since the biomechanics of gait on a motorised treadmill is significantly different compared to a non-motorised treadmill or overground walking [24]. This suggests that using a treadmill to investigate the effects of footwear in this population might lead to inaccurate data. As such, overground walking might offer a better alternative, as it is a daily activity for older adults, and allows the reliable measurement of 'non-artificial' locomotion [25, 22].

While overground walking has been used for footwear familiarisation in previous research testing different types of footwear in older adults, the protocols vary between studies [9, 26, 27]. Antonio and Perry [9] reported a 45 min footwear familiarisation period, but not enough information for methods' replication. Cudejko et al. [26] required the older adults to walk ten times on a ten-metre walkway for familiarisation with minimal (Primus Knit, Vivobarefoot™) and conventional footwear (Sketchers® with thick and soft midsole) using Melvin's et al. [5] familiarisation protocol which determined that 332 overground steps were required for footwear familiarisation in younger adults. Application of the same familiarisation methods to an older population [26] might thus be questioned as younger adults might familiarise differently with new footwear. The physiological changes that often accompany older age, such as skin hardness or peripheral neuropathy (nerve damage), that may reduce plantar sensitivity, and in turn reduce cutaneous feedback coming from the foot to the central nervous system [28], are less likely to affect the younger adult. Peterson et al. [27] indicated one minute of walking back and forth on a 25 m track for footwear familiarisation, with minimal footwear (Leguano® Classic),using a protocol from a previous study [25] where footwear was not evaluated and familiarisation trial duration not reported [25]. It is therefore unclear why Petersen et al. [27] used one minute.

Overall, little information and standardisation of footwear familiarisation with older adults exists. The number of steps required for footwear familiarisation in older adults is unknown, and it is unclear whether the participants took enough steps to become acquainted with the unfamiliar footwear in studies where familiarisation did not take place. This makes comparisons and results generalisation difficult. Considering that there were 703 million older adults around the world in 2019, with this number estimated to increase to 1.5 billion by 2050 [29], it is important to ensure that studies aimed at improving older adults' wellbeing, such as footwear comparison studies, are valid.

The aim of this study was to identify the number of steps required for healthy older adults to be familiarised with athletic footwear of different midsole thicknesses.

Methods

Participants

Twenty-six healthy and physically active community-dwelling older adults volunteered to participate in the study (Table 1). The sample size was determined with an a priori G*Power calculation [30]. The appropriate effect size was determined based on previous gait velocity differences found for this population [17]. To obtain a statistical power of β=0.80, d = 0.31, and α = 0.05, the estimated sample was 16 participants. Ten more participants were recruited to account for potential participant dropout or incomplete data sets.

Using a non-random purposive sampling strategy, community-dwelling older adults living in the Bedford Borough community (United Kingdom) were recruited via advertisements and word of mouth at local gyms, churches, choirs, and sports clubs. The participants needed to be aged 65 to 79 years old, with a UK shoe size of 5, 6, or 7 for females, and 8, 9, or 10 for males (due to shoe size availability) and able to walk unaided for 25 min. The exclusion criteria included balance impairment, multiple sclerosis, peripheral neuropathy, diabetes mellitus, lower limb amputation, prostheses (including joint replacement), dementia, hemiparesis, neurological disease (such as Alzheimer's or Parkinson's disease), major or mild cognitive impairment, and major or mild traumatic brain injury. In addition, participants were excluded if they had experienced foot or ankle surgery or lower limb musculoskeletal injury in the previous three months (due to inability to perform regular movement). Participants dependent on walking aids, such as a cane or walker, with major mobility impairments, or taking medication that could affect balance or stability were also excluded (medicines.org.uk/emc). Inclusion and exclusion criteria were assessed via self-report, and by a medical health questionnaire, which was completed prior to any testing.

All participants completed the Total Activity Measure 2 questionnaire [31] to collect information on their activity levels. The National Health Service physical activity guidelines for older adults were used to classify the participants as active [32], as they engaged in at least 150 min of moderate or 75 min of vigorous intensity activity per week, or a combination of both.

Footwear Conditions

All participants were required to walk in three footwear conditions. The characteristics of these commercially available footwear were provided by New Balance® as follows: 1) New Balance® REVlite 890v6, a neutral shoe with 6 mm drop height, blown rubber outsole, and midsole single density REVlite EVA foam (13 mm at forefoot, 19 mm under the heel); 2) New Balance® REVlite 1400v5, a neutral shoe with 10 mm drop height, blown rubber outsole, and midsole single density REVlite EVA foam (9.3 mm at forefoot, 19.3 mm under the heel); and 3) New Balance Minimus® 20v7, a minimalist shoe, with 4 mm drop height, thin Vibram rubber outsole, and midsole REVlite of the Prevail (5 mm at forefoot, 9 mm under the heel). All three footwear conditions had a hard and firm midsole (57C).

Procedures

A repeated-measures design was used. For safety reasons, the testing order was pre-determined rather than randomised. This decision was informed by past research indicating that transition from conventional to minimal footwear needs to be gradual due to placing new loads on the musculoskeletal system [33, 34], which in turn could influence the results. In addition, due to biologic injuries and insults that may accumulate over time, older adults typically present a high gait variability [35]. As such, the decision of non-randomising the testing order was also to mitigate more potential variability from acting as a confounder variable. For all these reasons, the testing order was assigned based on the midsole thickness of each footwear condition, from the thickest to the thinnest midsole as follows: 1) thick midsole (New Balance® REVlite 890v6); 2) moderate midsole (New Balance® REVlite 1400v5); and 3) thin midsole (New Balance® Minimus 20v7). The 890v6 was established as the thick midsole condition compared with the 1400v5, because the midsole of the 890v6 was thicker at the forefoot [11].

All participants wore identical new athletic socks supplied on arrival to the laboratory (TUUHAW). To prevent participant bias, the details of the investigation and characteristics of the three footwear conditions were not disclosed.

For the footwear fitting, the palpation method was used. The participants stood upright while the lead researcher palpated their hallux, to ensure a gap of 0.5 to 2.0 cm between the distal end of the hallux and the shoe end [36]. A dowelling rod was used to confirm that both the left and right shoelaces were secured with a similar level of tension to prevent heel slipping or mediolateral instability. This was achieved by checking the dowelling rod fitted inside the back of the shoes. At the end of shoe fitting, it was verbally confirmed by the participant that the shoes were comfortable and well-fitted. If a participant replied negatively, the shoes were re-fitted.

Walking protocol

The participants were instructed to walk at their normal comfortable speed on a 10 m track inside a laboratory on a flat floor. As continuous walking was not possible due to the laboratory setting, the participants were asked to turn clockwise at one end and anticlockwise at the other, to reduce asymmetrical fatigue. Prior to data collection, the participants were required to walk back and forth for one minute on the 10 m track for familiarisation with the testing procedures [27]. This was performed with the participants' own footwear, as they were asked to bring to the testing session their most frequently used outdoor shoes. The type of footwear worn were categorised using Menz and Sherrington's footwear assessment form [37], with ten participants wearing athletic footwear, eight walking shoes, three sandals, two Oxford shoes, two moccasins, and one participant wearing boots.

Following a five-minute seated rest, data collection began. Spatiotemporal gait data were collected using one metre bars (10 m total walkway) of Optojump (Optojump Next v1.5, Microgate, Perform Better Ltd). SmartSpeed light gates (SmartSpeed 2 Gate System, Fusion Sport, HaB) were positioned at the beginning and end of the Optojump track to measure 0-10 m time. Two trials of 200 steps were conducted with a seated rest period of five minute between the two trials. Following rest, a bipedal static postural test consisting of three 30 s trials was conducted, with this data to be reported in a subsequent study. All participants completed 400 steps for each footwear condition. To prevent fatigue, a five-minute seated rest between each footwear trial was provided.

Data Analysis

Data analyses were performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Spatiotemporal gait data were extracted from Optojump software (Optojump Next v1.5, Microgate, Perform Better Ltd) into Microsoft Excel for analysis. Gait speed ($m.s^{-1}$) for the 400 steps were calculated for each footwear condition. Walking time was extracted from the SmartSpeed software (SmartSpeed 2 Gate System, Fusion Sport, HaB) into Microsoft Excel to calculate how much time (min) the participants took to walk each 200 steps inside the 10 m track.

In order to identify the number of steps needed for footwear familiarisation, some assumptions were needed. First, that 400 steps would suffice for footwear familiarisation to occur. While Melvin et al. [5] recommended 332 steps, to account for potential increased gait variability due to the age of the population being studied [46], the present study cautiously assumed that by 400 steps participants would be familiarised. Second, that gait speed would be the best variable to investigate footwear familiarisation. Gait speed has been used as a reliable representation of walking steadiness in older adults [38] and as a physical function measure [39]. Thirdly, past research recommended the collection of at least 40 steps for observation of steady walking gait speed in older adults [40, 38]; therefore, it was assumed that averaging 40 steps would be appropriate in this footwear familiarisation protocol.

The first phase of analysis consisted of assessing steady state gait in each trial. To account for the acceleration and deceleration periods after each turn at the start and end of the 10 m track, the steps with ground contacts in the first and last 2.5 m of the track were removed [48, 18]. Next, outliers in the gait speed data were identified. This was achieved by determining a threshold that consisted of continuously averaging 40 steps [38, 40] and then calculating the upper and lower boundaries of two standard deviations [5]. The steps with gait speed data outside of this threshold were removed.

In the second phase of analysis, blocks of 40 steps from each trial were averaged and analysed, and a mean (SD) obtained for each of the following blocks: 0 to 40, 40 to 80, 80 to 120, 120 to 160, and 160 to 200 steps (trial 1); 200 to 240, 240 to 280, 280 to 320, 320 to 360, and 360 to 400 steps (trial 2). To investigate the variability within each 40 step block, the coefficient of variation (CoV%) was calculated (CoV% = SD/mean*100). Coefficient of variation values below 18% were considered low variability for this population [40]. Next, a threshold was determined to obtain steady state walking in each footwear condition following familiarisation. This was achieved by calculating the upper and lower boundaries (using two SD) for each block of 40 steps. The upper and lower boundaries from block 320 to 360 steps were used to identify familiarised gait for each participant.

The third and final phase of analysis consisted of analysing blocks of 40 steps from both trials and sequentially compared them with the familiarised gait thresholds established in the second phase of the analysis. Footwear familiarisation was assumed when the mean gait speed stabilised within an acceptable level, which occurred when the mean gait speed fell within the upper and lower boundaries from 320 to 360 steps and was subsequently maintained.

The procedures outlined in the three phases of analysis were conducted individually for each participant and the three footwear midsoles. Microsoft Excel frequency function was used to count how many participants needed 40 to 80, 80 to 120, 120 to 160 steps (etc.), to familiarise with each footwear condition.

Results

The participants' characteristics are presented in Table 1.

The results showed that steady state walking was observed with the use of 40 step average values. This was evidenced by the CoV%, which demonstrated an acceptable variability (9.4 to 12.2%) within each block of steps in both trials for the three footwear conditions. Both trials from three participants were removed from the dataset. One participant with the thick condition was excluded due to loss of data during the collection process, and two participants with the thin condition were excluded because they were unable to complete at least 40 steps of steady gait. All the other footwear conditions were included for these three participants.

The number of steps required for footwear familiarisation with the three footwear conditions and gait speed mean, SD, and CoV% for each block of steps are presented in Table 2. The results revealed that most participants were familiarised with the thick (*n*=18), moderate (*n*=20) and thin midsole (*n*=20) after walking 80 steps. The highest number of steps necessary for familiarisation was found in the thick midsole, with one participant requiring 320 steps. This was followed by the thin midsole, with two participants requiring 240 steps. The shortest familiarisation period was found for the moderate midsole, where all participants were familiarised after completing 160 steps. Regarding walking time to complete 200 steps, the participants took 1.52 ± 0.11 min in the thick midsole, 1.58 ± 0.15 min in the moderate midsole, and 1.49 ± 0.17 min in the thin midsole.

Discussion

The aim of this study was to identify the number of steps required for healthy older adults to be familiarised with athletic footwear of different midsole thicknesses. The findings revealed that, for individual participants, a minimum of 80 and a maximum of 320 steps were required for familiarisation. The number of familiarisation steps differed between participants and between footwear, suggesting that the shoe midsole thickness influenced the duration of the familiarisation period. Although a large number of participants were familiarised with the thick (*n*=18), moderate (*n*=20) and thin midsoles (*n*=20) after walking 80 steps, two participants required 240 familiarisation steps with the thin midsole, and one participant 320 familiarisation steps with the thick midsole. The moderate midsole had the shortest familiarisation period, as all participants were familiarised following completion of 160 steps. This may be explained by the moderate midsole being potentially the most similar in characteristics to the athletic footwear worn to the testing session by 10 of the participants, identified using the Menz and Sherrington criteria [37].

Despite having used a different population, equipment, methods, and footwear, the findings from this study are in line with Melvin et al. [5], who reported 332 steps needed for footwear familiarisation. The maximum number of steps observed in this study (320) were consistent with those required in the young adults (332) observed by Melvin et al. [5]. Due to the rigorous exclusion criteria imposed, the health status of the participants in the present study may partly explain the findings, where good physical health may manifest with better neuromuscular control and steady walking gait.

Additionally, the results support the use of 40 steps to be averaged as representative of normal gait in older adults [40]. As mentioned, this approach accounts for the intrinsic gait variability that is typically observed in older adults [35]. The participants from this study exhibited a steady and consistent walking gait within each block of steps, as evidenced by the CoV% for gait speed that ranged from 9.4 to 12.2% [40]. These findings reinforce that older adults can produce a steady and consistent walking gait within intervals of 40 consecutive steps, allowing the analysis and interpretation of reliable data that can be used to inform the footwear familiarisation process. It should be noted however that the outlier removal process described in the data analysis should be used to obtain this steady walking gait.

Although previous studies have not reported their footwear familiarisation details [26, 27], making direct comparisons problematic, it can be argued that Petersen et al. [27] might have not provided enough walking time for familiarisation with the minimal footwear. Based on the walking time findings of the present study, the older adults would have required approximately 2.10 min to walk 240 familiarisation steps, far more than the one minute provided by Petersen et al. [27]. The findings from the present study also suggest that the participants in Cudejko et al. [26] might have not been fully familiarised with the minimal and conventional footwear. This is because three participants from the present study required more than 200 steps for footwear familiarisation, which is equivalent to walking more than 100 m. As such, while different footwear was used in these previous studies, findings might need to be interpreted and applied with caution due to potential insufficient familiarisation with the testing footwear.

Overall, this study presents novel findings and makes an original contribution to the footwear research field by creating an evidence-based walking protocol for athletic footwear familiarisation in older adults. It provides new implications, suggesting that future studies investigating the effects of athletic footwear in healthy older adults should consider adopting a walking-based familiarisation protocol that includes a minimum of 320 steps. This approach accounts for variations in midsole thicknesses and potential individual differences between older adults. Implementing this practice ensures that all participants become familiarised with the footwear prior to experimental testing and facilitates comparisons between studies. It is also recommended that researchers provide details of their familiarisation process, analyse the data, and present their results. This way, future studies may use this information to further the knowledge of footwear familiarisation with older adults using different types of athletic footwear with different midsole thicknesses.

Limitations and Recommendations for Future Research

This study has a few limitations that should be addressed. Firstly, the testing order was non-randomised, which may have influenced the results; however, a similar and low CoV% found in all three footwear conditions suggested that learning effects were not present. Secondly, this study included healthy and physically active community-dwelling older adults aged 65 to 79 years old, as it was important to prevent comorbidities and a broader age group from acting as potential confounding variables. If applying this walking-based protocol to sedentary older adults and to those aged 80 years old and above, a minimum of 320 steps should be consider as previously mentioned, and the results should be generalised with caution beyond this age range. Thirdly, it should be acknowledged that the characteristics of the three footwear designs (i.e., drop height) may have played a role in the results, as it may have influenced the participants' performance. However, for a wider applicability of the results, it was important to use footwear commercially available. Fourthly, this walking-based protocol was established in a safe and controlled environment, using a flat laboratory floor. Thus this study has limited external validity, as in real-life scenarios all sorts of environmental factors might influence walking gait. Lastly, footwear familiarisation occurred across two trials collected during one visit. Short-term foot-memory can vary from day-to-day, or even with different footwear manufacturers and shoe styles. As such, it should be noted that this study reflects the short-term effects of wearing the athletic footwear tested in this study.

Considering that only one study quantified the number of steps necessary for familiarisation to different footwear [5], more investigation is advocated on this topic to further the knowledge of how footwear affects familiarisation in older adults. Additional insights into how different athletic footwear influences footwear familiarisation may provide valuable guidance for healthcare professionals and footwear manufacturers. This information will improve the validity of footwear interventions, by testing the footwear responses rather than the familiarisation. In addition, future research should establish and validate walking-based footwear familiarisation protocols using different footwear styles to expand the knowledge of footwear effects in older adults. Highlighted by the diverse footwear worn to the testing session by the participants, it is important to investigate how different outdoor footwear styles may influence older adults' postural stability and in turn contribute to falls.

Conclusion

In summary, to our knowledge, this may be the first published study to establish the number of familiarisation steps required for healthy older adults to familiarise with athletic footwear of different midsole thicknesses. The results showed that the number of familiarisation steps differed between participants and between footwear midsoles. We recommend using this evidence-based walking familiarisation protocol in healthy older adults and a minimum of 320 familiarisation steps to account for both individual differences and midsole thicknesses. This will ensure the analysis of the actual footwear effects rather than the familiarisation with the footwear.

Statement of Ethics

This study protocol was reviewed and approved by the University of Bedfordshire Research Ethics Committee, Institute for Sport and Physical Activity Research (ISPAR) Ethics Panel, approval number 2021ISPAR013. Written informed consent was obtained from all the participants prior to any testing in accordance with the Declaration of Helsinki.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

D.S. developed the study design, collected analysed the data, and wrote the manuscript. I.F., A.M. and L.C. assisted with the study design, data analysis, writing, review and the editing of the manuscript.

Data Availability Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

References

1 Age UK. Fitter Fit. Available from: https://www.ageuk.org.uk/information-advice/health-wellbeing/exercise/fitter-feet/.

2 NHS. Footwear Guide. Available from: https://www.lpft.nhs.uk/our-services/older-adults/inpatient-wards/footwear-guide.

3 Matsas, A, Nicholas T, McBurney, H. Knee joint kinematics from familiarised treadmill walking can be generalised to overground walking in young unimpaired subjects. Gait Posture.2000;11(1):46-53.

4 Davis, A, Haines, T, Williams, C. Do footwear styles cause falls or increase falls risk in healthy older adults? A systematic review. Footwear Science.2019;11(1):13-23.

5 Melvin, JMA, Preece, S, Nester, CJ, Howard, D. An investigation into plantar pressure measurement protocols for footwear research. Gait Posture.2014;40(4):682-687.

6 Azhar, AN, Munteanu, SE, Menz, HB. Effects of supportive and minimalist footwear on standing balance and walking stability in older women. J Foot Ankle Res.2023;16:38.

7 Brenton-Rule, A, Bassett, S, Walsh, A, Rome, K. The evaluation of walking footwear on postural stability in healthy older adults: An exploratory study. Clin Biomech.2011;26(8):885–887.

8 Broscheid, KC, Astrid Z. Influence of barefoot, minimalist, and standard footwear conditions on gait and balance in healthy older adults. J Am Geriatr Soc.2016;64(2):435-437.

9 Antonio, PJ, Perry, SD. Quantifying stair gait stability in young and older adults, with modifications to insole hardness. Gait Posture.2014;40(3):429-434.

10 Hollander, K, Petersen, E, Zech, A, Hamacher, D. Effects of barefoot vs shod walking during indoor and outdoor conditions in younger and older adults. Gait Posture.2022;95:284-291.

11 Robbins, S, Gouw, GJ, McClaran, J. Shoe sole thickness and hardness influence balance in older men. J Am Geriatr Soc.1992;40(11):1089-1094.

12 Robbins, S, Waked, E, Allard, P, McClaran, J, Krouglicof, N. Foot position awareness in younger and older men: The influence of footwear sole properties. J Am Geriatr Soc.1997;45(1):61–66.

13 Waked, E, Robbins, S, McClaran, J. The effect of footwear midsole hardness and thickness on proprioception and stability in older men. J Test Eval.1997;25(1):143–148.

14 Zhang, X, Tan, SS, Franse, CB, Alhambra-Borrás, T, Durá-Ferrandis, E, Bilajac, L, Markaki, A et al. Association between physical, psychological and social frailty and health-related quality of life among older people. Eur J Public Health.2019 29;(5):936-942.

15 Viseux, FJ. The sensory role of the sole of the foot: review and update on clinical perspectives. Neurophysiol Clin.2020;50(1): 55-68.

16 Davis, A, Murphy, A, Haines, TP. Good for Older Ladies, Not Me How Elderly Women Choose Their Shoes. J Am Podiatr Med Assoc.2013;103(6):465-470.

17 Hollander, K, Petersen, E, Zech, A, Hamacher, D. Effects of barefoot vs shod walking during indoor and outdoor conditions in younger and older adults. Gait Posture.2022;95:284-291.

18 Arnold, BJ, Weeks, BK, Horan, SA. An examination of treadmill running familiarisation in barefoot and shod conditions in healthy men. J Sports Sci.2019;37(1):5-12.

19 TenBroek, TM, Rodrigues, P, Frederick, EC, Hamill, J. Effects of unknown footwear midsole thickness on running kinematics within the initial six minutes of running. Footwear Sci. 2013;5(1):27-37.

20 Lindorfer, J, Kroell, J, Schwameder, H. Familiarisation of novice and experienced treadmill users during a running session: Group specific evidence, time and individual patterns. Hum Mov Sci.2020;69:102530.

21 Nagano, H, Begg, RK, Sparrow, WA, Taylor, S. A comparison of treadmill and overground walking effects on step cycle asymmetry in young and older individuals. J Appl Biomech.2013;29(2):188-193.

22 Marsh, AP, Katula, JA, Pacchia, C.F, Johnson, LC, Koury, KL, Rejeski, WJ. Effect of treadmill and overground walking on function and attitudes in older adults. Med Sci Sports Exerc.2006;38(6):1157-1164.

23 Siragy, T, Russo, Y, Young, W, Lamb, SE. Comparison of over-ground and treadmill perturbations for simulation of real-world slips and trips: A systematic review. Gait Posture.2022; 100:201-209.

24 Montgomery, G, Abt, G, Dobson, C, Smith, T., Ditroilo, M. Tibial impacts and muscle activation during walking, jogging and running when performed overground, and on motorised and non-motorised treadmills. Gait Posture.2016; 49:120-126.

25 Hamacher, D, Hamacher, D, Krowicki, M, Schega, L. Between-day test–retest reliability of gait variability in older individuals improves with a familiarization trial. Aging Clin Exp Res.2017;29:327-329.

26 Cudejko, T, Gardiner, J, Akpan, A, D'Août, K. Minimal shoes improve stability and mobility in persons with a history of falls. Sci Rep.2020; 10(1):1-10.

27 Petersen, E, Zech, A, Hamacher, D. Walking barefoot vs. with minimalist footwear–influence on gait in younger and older adults. BMC Geriatrics.2020;20(1):1-6.

28 Periyasamy, R, Anand, S, Ammini, AC. The effect of aging on the hardness of foot sole skin: a preliminary study.Foot.2012;22(2):95-99.

29 World Population Ageing 2019: Highlights. Available from: digitallibrary.un.org/record/3846855?ln=en&v=pdf.

30 Faul, F, Erdfelder, E, Lang, AG,Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods.2007;39:175-191.

31 Orrell, A, Doherty, P, Miles, J, Lewin, R. Development and validation of a very brief questionnaire measure of physical activity in adults with coronary heart disease. Eur J Prev Cardiol.2007;14(5):615-623.

32 NHS;2021 Physical activity guidelines for older adults. Available from: https://www.nhs.uk/live-well/exercise/exercise-guidelines/physical-activity-guidelines-older-adults.

33 Davis, IS, Hollander, K, Lieberman, DE, Ridge, ST, Sacco, IC, Wearing, SC. Stepping back to minimal footwear: applications across the lifespan. Exerc Sport Sci Rev. 2021;49(4):228-243.

34 Hollander, K, Davis, IS. Chapter 39 - Minimal Shoes: Restoring Natural Running Mechanics in Foot and Ankle Biomechanics. In: WR, ST, editors. Academic Press;2023: 623-634.

35 Callisaya, ML, Blizzard, L, Schmidt, MD, McGinley, JL, Srikanth, VK. Ageing and gait variability—a population-based study of older people. Age Ageing.2010;39(2):191-197.

36 Menz, HB, Morris, ME, Lord, SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. J Gerontol A Biol Sci Med Sci.2005;60(12): 1546-1552.

37 Menz, HB, Sherrington, C. The footwear assessment form: a reliable clinical tool to assess footwear characteristics of relevance to postural stability in older adults. Clin Rehabil.2000;14(6):657-664.

38 Lindemann, U, Najafi, B, Zijlstra, W, Hauer, K, Muche, R, Becker, C, et al. Distance to achieve steady state walking speed in frail elderly persons. Gait Posture.2008;27(1):91-96.

39 Rydwik, E, Bergland, A, Forsen, L, Frändin, K. Investigation into the reliability and validity of the measurement of elderly people's clinical walking speed: a systematic review. Physiother Theory Pract.2012;28(3):238-256.

40 Hollman, JH, McDade, EM, Petersen, RC. Normative spatiotemporal gait parameters in older adults. Gait Posture.2011;34(1):111-118.

Research Article

Identifying the Number of Steps Required for Familiarisation to Athletic Footwear in Healthy Older Adults

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Abstract

Introduction: Research on athletic footwear familiarisation within an older population is sparse. This is problematic because unfamiliar footwear may act as a new perturbation and modify older adults' walking gait and stability. In addition, while athletic footwear has been suggested to enhance older adults' comfort and support during activities of daily living, the necessary period for familiarisation with athletic footwear is unknown. Therefore, this study aimed to identify the number of steps required for older adults to be familiarised with athletic footwear of different midsole thicknesses. ***Methods:*** Twenty-six healthy and physically active community-dwelling older adults, 21 females (71.1 ± 4.5 years; 164.5 ± 5.3 cm; 68.4 ± 11.4 kg) and five males (70.6 ± 2.3 years; 175.2 ± 7.8 cm; 72.8 ± 9.7 kg) completed a walking-based protocol. Participants walked two trials of 200 steps at their habitual speed on a 10 m track of an optical measurement system in three footwear conditions: 1) New Balance® REVlite 890v6 (thick midsole); 2) New Balance® REVlite 1400v5 (moderate midsole); and 3) New Balance® Minimus 20v7 (thin midsole). Gait speed ($m.s^{-1}$) and walking time (min) were analysed for each participant over the 400 steps. Number of required familiarisation steps were established over three analysis phases, consisting of steady state gait assessment, averaging and analysis of blocks of 40 steps, and sequentially comparing these steps with a pre-determined threshold. Footwear familiarisation was assumed when the mean gait speed fell within an acceptable level (± 2 SD from 320 to 360 step values) and subsequently maintained. ***Results:*** Most participants were familiarised with all three footwear conditions (thick *n*= 18; moderate and thin *n*= 20) after walking 80 steps. For all participants, the moderate midsole had the shortest familiarisation period (160 steps). The highest number of familiarisation steps were found in the thick (320 steps) and thin midsoles (240 steps) for some participants. ***Conclusion:*** A minimum of 320 familiarisation steps is recommended to account for both individual differences and midsole thicknesses. Implementing this walking-based footwear familiarisation protocol would improve validity of future studies, ensuring they analyse footwear effects rather than familiarisation with the footwear.

Introduction

Athletic footwear has been recommended to improve older adults' comfort and support during activities of daily living [1,2]. However, the necessary period for footwear familiarisation in older adults is poorly recognised. Familiarisation is defined as a short-term adaptation in which variance in repeated measures for a particular variable stabilises to an acceptable level within one session [3]. This process is particularly pertinent when analysing footwear effects [4,5]. However, previous studies investigating the effects of footwear on older adults' postural stability and gait failed to report their familiarisation protocol [6, 7, 8], provided insufficient information for method replication [9], or used protocols that lead to uncertainties whether the familiarisation was for the study procedures or for the footwear [10, 11, 12, 13]. This is problematic because, more than the style of footwear, the lack of familiarisation with a particular type of footwear has been suggested to be a more substantial contributor to fall risk [4], as footwear has been indicated as an extrinsic risk factor associated with falls in this population [14]. Sensory information from plantar cutaneous afferents and foot muscles induces intrinsic automatic postural adjustments in response to new stimuli [15]. Unfamiliar footwear may thus act as a perturbation to older adults' static and dynamic postural stability, and lead to potential alterations in the lower limb biomechanics [16], such as walking gait changes [8, 17], which in turn may increase fall risk. As such, footwear familiarisation is essential before any experimental testing to allow the participants to become acquainted with unfamiliar shoes [5]. Only then, will the results reflect the shoe effects, as opposed to data that may reflect intrinsic postural changes associated with being unaccustomed to a particular type of footwear [5].

Research on athletic footwear typically uses a treadmill for individuals to walk or run to become familiarised with unfamiliar shoes [18, 19]. This is because this equipment allows the capture of repetitive gait cycles in a controlled environment, whereby loading and locomotion patterns can be analysed [20]. Once a stable and consistent pattern is observed in the treadmill locomotion, which is preceded by a change in the variable of interest, familiarisation is assumed [18]. Treadmills may however not be the best choice for footwear familiarisation with older adults. Compared with overground walking, treadmill use has been shown to reduce older adults' gait speed and increase the double support phase time [21], possibly because older adults feel unstable while walking on a treadmill due to being an unfamiliar ergometer for this population. Indeed, previous research reported that older adults tend to use the treadmill handrail to feel secure [22]. In addition, walking on a treadmill may influence older adults' stepping and postural responses [23], since the biomechanics of gait on a motorised treadmill is significantly different compared to a non-motorised treadmill or overground walking [24]. This suggests that using a treadmill to investigate the effects of footwear in this population might lead to inaccurate data. As such, overground walking might offer a better alternative, as it is a daily activity for older adults, and allows the reliable measurement of 'non-artificial' locomotion [25, 22].

While overground walking has been used for footwear familiarisation in previous research testing different types of footwear in older adults, the protocols vary between studies [9, 26, 27]. Antonio and Perry [9] reported a 45 min footwear familiarisation period, but not enough information for methods' replication. Cudejko et al. [26] required the older adults to walk ten times on a ten-metre walkway for familiarisation with minimal (Primus Knit, Vivobarefoot™) and conventional footwear (Sketchers® with thick and soft midsole) using Melvin's et al. [5] familiarisation protocol which determined that 332 overground steps were required for footwear familiarisation in younger adults. Application of the same familiarisation methods to an older population [26] might thus be questioned as younger adults might familiarise differently with new footwear. The physiological changes that often accompany older age, such as skin hardness or peripheral neuropathy (nerve damage), that may reduce plantar sensitivity, and in turn reduce cutaneous feedback coming from the foot to the central nervous system [28], are less likely to affect the younger adult. Peterson et al. [27] indicated one minute of walking back and forth on a 25 m track for footwear familiarisation, with minimal footwear (Leguano® Classic),using a protocol from a previous study [25] where footwear was not evaluated and familiarisation trial duration not reported [25]. It is therefore unclear why Petersen et al. [27] used one minute.

Overall, little information and standardisation of footwear familiarisation with older adults exists. The number of steps required for footwear familiarisation in older adults is unknown, and it is unclear whether the participants took enough steps to become acquainted with the unfamiliar footwear in studies where familiarisation did not take place. This makes comparisons and results generalisation difficult. Considering that there were 703 million older adults around the world in 2019, with this number estimated to increase to 1.5 billion by 2050 [29], it is important to ensure that studies aimed at improving older adults' wellbeing, such as footwear comparison studies, are valid.

The aim of this study was to identify the number of steps required for healthy older adults to be familiarised with athletic footwear of different midsole thicknesses.

Methods

Participants

Twenty-six healthy and physically active community-dwelling older adults volunteered to participate in the study (Table 1). The sample size was determined with an a priori G*Power calculation [30]. The appropriate effect size was determined based on previous gait velocity differences found for this population [17]. To obtain a statistical power of β=0.80, d = 0.31, and α = 0.05, the estimated sample was 16 participants. Ten more participants were recruited to account for potential participant dropout or incomplete data sets.

Using a non-random purposive sampling strategy, community-dwelling older adults living in the Bedford Borough community (United Kingdom) were recruited via advertisements and word of mouth at local gyms, churches, choirs, and sports clubs. The participants needed to be aged 65 to 79 years old, with a UK shoe size of 5, 6, or 7 for females, and 8, 9, or 10 for males (due to shoe size availability) and able to walk unaided for 25 min. The exclusion criteria included balance impairment, multiple sclerosis, peripheral neuropathy, diabetes mellitus, lower limb amputation, prostheses (including joint replacement), dementia, hemiparesis, neurological disease (such as Alzheimer's or Parkinson's disease), major or mild cognitive impairment, and major or mild traumatic brain injury. In addition, participants were excluded if they had experienced foot or ankle surgery or lower limb musculoskeletal injury in the previous three months (due to inability to perform regular movement). Participants dependent on walking aids, such as a cane or walker, with major mobility impairments, or taking medication that could affect balance or stability were also excluded (medicines.org.uk/emc). Inclusion and exclusion criteria were assessed via self-report, and by a medical health questionnaire, which was completed prior to any testing.

All participants completed the Total Activity Measure 2 questionnaire [31] to collect information on their activity levels. The National Health Service physical activity guidelines for older adults were used to classify the participants as active [32], as they engaged in at least 150 min of moderate or 75 min of vigorous intensity activity per week, or a combination of both.

Footwear Conditions

All participants were required to walk in three footwear conditions. The characteristics of these commercially available footwear were provided by New Balance® as follows: 1) New Balance® REVlite 890v6, a neutral shoe with 6 mm drop height, blown rubber outsole, and midsole single density REVlite EVA foam (13 mm at forefoot, 19 mm under the heel); 2) New Balance® REVlite 1400v5, a neutral shoe with 10 mm drop height, blown rubber outsole, and midsole single density REVlite EVA foam (9.3 mm at forefoot, 19.3 mm under the heel); and 3) New Balance Minimus® 20v7, a minimalist shoe, with 4 mm drop height, thin Vibram rubber outsole, and midsole REVlite of the Prevail (5 mm at forefoot, 9 mm under the heel). All three footwear conditions had a hard and firm midsole (57C).

Procedures

A repeated-measures design was used. For safety reasons, the testing order was pre-determined rather than randomised. This decision was informed by past research indicating that transition from conventional to minimal footwear needs to be gradual due to placing new loads on the musculoskeletal system [33, 34], which in turn could influence the results. In addition, due to biologic injuries and insults that may accumulate over time, older adults typically present a high gait variability [35]. As such, the decision of non-randomising the testing order was also to mitigate more potential variability from acting as a confounder variable. For all these reasons, the testing order was assigned based on the midsole thickness of each footwear condition, from the thickest to the thinnest midsole as follows: 1) thick midsole (New Balance® REVlite 890v6); 2) moderate midsole (New Balance® REVlite 1400v5); and 3) thin midsole (New Balance® Minimus 20v7). The 890v6 was established as the thick midsole condition compared with the 1400v5, because the midsole of the 890v6 was thicker at the forefoot [11].

All participants wore identical new athletic socks supplied on arrival to the laboratory (TUUHAW). To prevent participant bias, the details of the investigation and characteristics of the three footwear conditions were not disclosed.

For the footwear fitting, the palpation method was used. The participants stood upright while the lead researcher palpated their hallux, to ensure a gap of 0.5 to 2.0 cm between the distal end of the hallux and the shoe end [36]. A dowelling rod was used to confirm that both the left and right shoelaces were secured with a similar level of tension to prevent heel slipping or mediolateral instability. This was achieved by checking the dowelling rod fitted inside the back of the shoes. At the end of shoe fitting, it was verbally confirmed by the participant that the shoes were comfortable and well-fitted. If a participant replied negatively, the shoes were re-fitted.

Walking protocol

The participants were instructed to walk at their normal comfortable speed on a 10 m track inside a laboratory on a flat floor. As continuous walking was not possible due to the laboratory setting, the participants were asked to turn clockwise at one end and anticlockwise at the other, to reduce asymmetrical fatigue. Prior to data collection, the participants were required to walk back and forth for one minute on the 10 m track for familiarisation with the testing procedures [27]. This was performed with the participants' own footwear, as they were asked to bring to the testing session their most frequently used outdoor shoes. The type of footwear worn were categorised using Menz and Sherrington's footwear assessment form [37], with ten participants wearing athletic footwear, eight walking shoes, three sandals, two Oxford shoes, two moccasins, and one participant wearing boots.

Following a five-minute seated rest, data collection began. Spatiotemporal gait data were collected using one metre bars (10 m total walkway) of Optojump (Optojump Next v1.5, Microgate, Perform Better Ltd). SmartSpeed light gates (SmartSpeed 2 Gate System, Fusion Sport, HaB) were positioned at the beginning and end of the Optojump track to measure 0-10 m time. Two trials of 200 steps were conducted with a seated rest period of five minute between the two trials. Following rest, a bipedal static postural test consisting of three 30 s trials was conducted, with this data to be reported in a subsequent study. All participants completed 400 steps for each footwear condition. To prevent fatigue, a five-minute seated rest between each footwear trial was provided.

Data Analysis

Data analyses were performed using Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Spatiotemporal gait data were extracted from Optojump software (Optojump Next v1.5, Microgate, Perform Better Ltd) into Microsoft Excel for analysis. Gait speed ($m.s^{-1}$) for the 400 steps were calculated for each footwear condition. Walking time was extracted from the SmartSpeed software (SmartSpeed 2 Gate System, Fusion Sport, HaB) into Microsoft Excel to calculate how much time (min) the participants took to walk each 200 steps inside the 10 m track.

In order to identify the number of steps needed for footwear familiarisation, some assumptions were needed. First, that 400 steps would suffice for footwear familiarisation to occur. While Melvin et al. [5] recommended 332 steps, to account for potential increased gait variability due to the age of the population being studied [46], the present study cautiously assumed that by 400 steps participants would be familiarised. Second, that gait speed would be the best variable to investigate footwear familiarisation. Gait speed has been used as a reliable representation of walking steadiness in older adults [38] and as a physical function measure [39]. Thirdly, past research recommended the collection of at least 40 steps for observation of steady walking gait speed in older adults [40, 38]; therefore, it was assumed that averaging 40 steps would be appropriate in this footwear familiarisation protocol.

The first phase of analysis consisted of assessing steady state gait in each trial. To account for the acceleration and deceleration periods after each turn at the start and end of the 10 m track, the steps with ground contacts in the first and last 2.5 m of the track were removed [48, 18]. Next, outliers in the gait speed data were identified. This was achieved by determining a threshold that consisted of continuously averaging 40 steps [38, 40] and then calculating the upper and lower boundaries of two standard deviations [5]. The steps with gait speed data outside of this threshold were removed.

In the second phase of analysis, blocks of 40 steps from each trial were averaged and analysed, and a mean (SD) obtained for each of the following blocks: 0 to 40, 40 to 80, 80 to 120, 120 to 160, and 160 to 200 steps (trial 1); 200 to 240, 240 to 280, 280 to 320, 320 to 360, and 360 to 400 steps (trial 2). To investigate the variability within each 40 step block, the coefficient of variation (CoV%) was calculated (CoV% = SD/mean*100). Coefficient of variation values below 18% were considered low variability for this population [40]. Next, a threshold was determined to obtain steady state walking in each footwear condition following familiarisation. This was achieved by calculating the upper and lower boundaries (using two SD) for each block of 40 steps. The upper and lower boundaries from block 320 to 360 steps were used to identify familiarised gait for each participant.

The third and final phase of analysis consisted of analysing blocks of 40 steps from both trials and sequentially compared them with the familiarised gait thresholds established in the second phase of the analysis. Footwear familiarisation was assumed when the mean gait speed stabilised within an acceptable level, which occurred when the mean gait speed fell within the upper and lower boundaries from 320 to 360 steps and was subsequently maintained.

The procedures outlined in the three phases of analysis were conducted individually for each participant and the three footwear midsoles. Microsoft Excel frequency function was used to count how many participants needed 40 to 80, 80 to 120, 120 to 160 steps (etc.), to familiarise with each footwear condition.

Results

The participants' characteristics are presented in Table 1.

The results showed that steady state walking was observed with the use of 40 step average values. This was evidenced by the CoV%, which demonstrated an acceptable variability (9.4 to 12.2%) within each block of steps in both trials for the three footwear conditions. Both trials from three participants were removed from the dataset. One participant with the thick condition was excluded due to loss of data during the collection process, and two participants with the thin condition were excluded because they were unable to complete at least 40 steps of steady gait. All the other footwear conditions were included for these three participants.

The number of steps required for footwear familiarisation with the three footwear conditions and gait speed mean, SD, and CoV% for each block of steps are presented in Table 2. The results revealed that most participants were familiarised with the thick (*n*=18), moderate (*n*=20) and thin midsole (*n*=20) after walking 80 steps. The highest number of steps necessary for familiarisation was found in the thick midsole, with one participant requiring 320 steps. This was followed by the thin midsole, with two participants requiring 240 steps. The shortest familiarisation period was found for the moderate midsole, where all participants were familiarised after completing 160 steps. Regarding walking time to complete 200 steps, the participants took 1.52 ± 0.11 min in the thick midsole, 1.58 ± 0.15 min in the moderate midsole, and 1.49 ± 0.17 min in the thin midsole.

Discussion

The aim of this study was to identify the number of steps required for healthy older adults to be familiarised with athletic footwear of different midsole thicknesses. The findings revealed that, for individual participants, a minimum of 80 and a maximum of 320 steps were required for familiarisation. The number of familiarisation steps differed between participants and between footwear, suggesting that the shoe midsole thickness influenced the duration of the familiarisation period. Although a large number of participants were familiarised with the thick (*n*=18), moderate (*n*=20) and thin midsoles (*n*=20) after walking 80 steps, two participants required 240 familiarisation steps with the thin midsole, and one participant 320 familiarisation steps with the thick midsole. The moderate midsole had the shortest familiarisation period, as all participants were familiarised following completion of 160 steps. This may be explained by the moderate midsole being potentially the most similar in characteristics to the athletic footwear worn to the testing session by 10 of the participants, identified using the Menz and Sherrington criteria [37].

Despite having used a different population, equipment, methods, and footwear, the findings from this study are in line with Melvin et al. [5], who reported 332 steps needed for footwear familiarisation. The maximum number of steps observed in this study (320) were consistent with those required in the young adults (332) observed by Melvin et al. [5]. Due to the rigorous exclusion criteria imposed, the health status of the participants in the present study may partly explain the findings, where good physical health may manifest with better neuromuscular control and steady walking gait.

Additionally, the results support the use of 40 steps to be averaged as representative of normal gait in older adults [40]. As mentioned, this approach accounts for the intrinsic gait variability that is typically observed in older adults [35]. The participants from this study exhibited a steady and consistent walking gait within each block of steps, as evidenced by the CoV% for gait speed that ranged from 9.4 to 12.2% [40]. These findings reinforce that older adults can produce a steady and consistent walking gait within intervals of 40 consecutive steps, allowing the analysis and interpretation of reliable data that can be used to inform the footwear familiarisation process. It should be noted however that the outlier removal process described in the data analysis should be used to obtain this steady walking gait.

Although previous studies have not reported their footwear familiarisation details [26, 27], making direct comparisons problematic, it can be argued that Petersen et al. [27] might have not provided enough walking time for familiarisation with the minimal footwear. Based on the walking time findings of the present study, the older adults would have required approximately 2.10 min to walk 240 familiarisation steps, far more than the one minute provided by Petersen et al. [27]. The findings from the present study also suggest that the participants in Cudejko et al. [26] might have not been fully familiarised with the minimal and conventional footwear. This is because three participants from the present study required more than 200 steps for footwear familiarisation, which is equivalent to walking more than 100 m. As such, while different footwear was used in these previous studies, findings might need to be interpreted and applied with caution due to potential insufficient familiarisation with the testing footwear.

Overall, this study presents novel findings and makes an original contribution to the footwear research field by creating an evidence-based walking protocol for athletic footwear familiarisation in older adults. It provides new implications, suggesting that future studies investigating the effects of athletic footwear in healthy older adults should consider adopting a walking-based familiarisation protocol that includes a minimum of 320 steps. This approach accounts for variations in midsole thicknesses and potential individual differences between older adults. Implementing this practice ensures that all participants become familiarised with the footwear prior to experimental testing and facilitates comparisons between studies. It is also recommended that researchers provide details of their familiarisation process, analyse the data, and present their results. This way, future studies may use this information to further the knowledge of footwear familiarisation with older adults using different types of athletic footwear with different midsole thicknesses.

Limitations and Recommendations for Future Research

This study has a few limitations that should be addressed. Firstly, the testing order was non-randomised, which may have influenced the results; however, a similar and low CoV% found in all three footwear conditions suggested that learning effects were not present. Secondly, this study included healthy and physically active community-dwelling older adults aged 65 to 79 years old, as it was important to prevent comorbidities and a broader age group from acting as potential confounding variables. If applying this walking-based protocol to sedentary older adults and to those aged 80 years old and above, a minimum of 320 steps should be consider as previously mentioned, and the results should be generalised with caution beyond this age range. Thirdly, it should be acknowledged that the characteristics of the three footwear designs (i.e., drop height) may have played a role in the results, as it may have influenced the participants' performance. However, for a wider applicability of the results, it was important to use footwear commercially available. Fourthly, this walking-based protocol was established in a safe and controlled environment, using a flat laboratory floor. Thus this study has limited external validity, as in real-life scenarios all sorts of environmental factors might influence walking gait. Lastly, footwear familiarisation occurred across two trials collected during one visit. Short-term foot-memory can vary from day-to-day, or even with different footwear manufacturers and shoe styles. As such, it should be noted that this study reflects the short-term effects of wearing the athletic footwear tested in this study.

Considering that only one study quantified the number of steps necessary for familiarisation to different footwear [5], more investigation is advocated on this topic to further the knowledge of how footwear affects familiarisation in older adults. Additional insights into how different athletic footwear influences footwear familiarisation may provide valuable guidance for healthcare professionals and footwear manufacturers. This information will improve the validity of footwear interventions, by testing the footwear responses rather than the familiarisation. In addition, future research should establish and validate walking-based footwear familiarisation protocols using different footwear styles to expand the knowledge of footwear effects in older adults. Highlighted by the diverse footwear worn to the testing session by the participants, it is important to investigate how different outdoor footwear styles may influence older adults' postural stability and in turn contribute to falls.

Conclusion

In summary, to our knowledge, this may be the first published study to establish the number of familiarisation steps required for healthy older adults to familiarise with athletic footwear of different midsole thicknesses. The results showed that the number of familiarisation steps differed between participants and between footwear midsoles. We recommend using this evidence-based walking familiarisation protocol in healthy older adults and a minimum of 320 familiarisation steps to account for both individual differences and midsole thicknesses. This will ensure the analysis of the actual footwear effects rather than the familiarisation with the footwear.

Statement of Ethics

This study protocol was reviewed and approved by the University of Bedfordshire Research Ethics Committee, Institute for Sport and Physical Activity Research (ISPAR) Ethics Panel, approval number 2021ISPAR013. Written informed consent was obtained from all the participants prior to any testing in accordance with the Declaration of Helsinki.

Conflict of Interest Statement

The authors have no conflicts of interest to declare.

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Author Contributions

D.S. developed the study design, collected analysed the data, and wrote the manuscript. I.F., A.M. and L.C. assisted with the study design, data analysis, writing, review and the editing of the manuscript.

Data Availability Statement

All data generated or analysed during this study are included in this article. Further enquiries can be directed to the corresponding author.

References

1 Age UK. Fitter Fit. Available from: https://www.ageuk.org.uk/information-advice/health-wellbeing/exercise/fitter-feet/.

2 NHS. Footwear Guide. Available from: https://www.lpft.nhs.uk/our-services/older-adults/inpatient-wards/footwear-guide.

3 Matsas, A, Nicholas T, McBurney, H. Knee joint kinematics from familiarised treadmill walking can be generalised to overground walking in young unimpaired subjects. Gait Posture.2000;11(1):46-53.

4 Davis, A, Haines, T, Williams, C. Do footwear styles cause falls or increase falls risk in healthy older adults? A systematic review. Footwear Science.2019;11(1):13-23.

5 Melvin, JMA, Preece, S, Nester, CJ, Howard, D. An investigation into plantar pressure measurement protocols for footwear research. Gait Posture.2014;40(4):682-687.

6 Azhar, AN, Munteanu, SE, Menz, HB. Effects of supportive and minimalist footwear on standing balance and walking stability in older women. J Foot Ankle Res.2023;16:38.

7 Brenton-Rule, A, Bassett, S, Walsh, A, Rome, K. The evaluation of walking footwear on postural stability in healthy older adults: An exploratory study. Clin Biomech.2011;26(8):885–887.

8 Broscheid, KC, Astrid Z. Influence of barefoot, minimalist, and standard footwear conditions on gait and balance in healthy older adults. J Am Geriatr Soc.2016;64(2):435-437.

9 Antonio, PJ, Perry, SD. Quantifying stair gait stability in young and older adults, with modifications to insole hardness. Gait Posture.2014;40(3):429-434.

10 Hollander, K, Petersen, E, Zech, A, Hamacher, D. Effects of barefoot vs shod walking during indoor and outdoor conditions in younger and older adults. Gait Posture.2022;95:284-291.

11 Robbins, S, Gouw, GJ, McClaran, J. Shoe sole thickness and hardness influence balance in older men. J Am Geriatr Soc.1992;40(11):1089-1094.

12 Robbins, S, Waked, E, Allard, P, McClaran, J, Krouglicof, N. Foot position awareness in younger and older men: The influence of footwear sole properties. J Am Geriatr Soc.1997;45(1):61–66.

13 Waked, E, Robbins, S, McClaran, J. The effect of footwear midsole hardness and thickness on proprioception and stability in older men. J Test Eval.1997;25(1):143–148.

14 Zhang, X, Tan, SS, Franse, CB, Alhambra-Borrás, T, Durá-Ferrandis, E, Bilajac, L, Markaki, A et al. Association between physical, psychological and social frailty and health-related quality of life among older people. Eur J Public Health.2019 29;(5):936-942.

15 Viseux, FJ. The sensory role of the sole of the foot: review and update on clinical perspectives. Neurophysiol Clin.2020;50(1): 55-68.

16 Davis, A, Murphy, A, Haines, TP. Good for Older Ladies, Not Me How Elderly Women Choose Their Shoes. J Am Podiatr Med Assoc.2013;103(6):465-470.

17 Hollander, K, Petersen, E, Zech, A, Hamacher, D. Effects of barefoot vs shod walking during indoor and outdoor conditions in younger and older adults. Gait Posture.2022;95:284-291.

18 Arnold, BJ, Weeks, BK, Horan, SA. An examination of treadmill running familiarisation in barefoot and shod conditions in healthy men. J Sports Sci.2019;37(1):5-12.

19 TenBroek, TM, Rodrigues, P, Frederick, EC, Hamill, J. Effects of unknown footwear midsole thickness on running kinematics within the initial six minutes of running. Footwear Sci. 2013;5(1):27-37.

20 Lindorfer, J, Kroell, J, Schwameder, H. Familiarisation of novice and experienced treadmill users during a running session: Group specific evidence, time and individual patterns. Hum Mov Sci.2020;69:102530.

21 Nagano, H, Begg, RK, Sparrow, WA, Taylor, S. A comparison of treadmill and overground walking effects on step cycle asymmetry in young and older individuals. J Appl Biomech.2013;29(2):188-193.

22 Marsh, AP, Katula, JA, Pacchia, C.F, Johnson, LC, Koury, KL, Rejeski, WJ. Effect of treadmill and overground walking on function and attitudes in older adults. Med Sci Sports Exerc.2006;38(6):1157-1164.

23 Siragy, T, Russo, Y, Young, W, Lamb, SE. Comparison of over-ground and treadmill perturbations for simulation of real-world slips and trips: A systematic review. Gait Posture.2022; 100:201-209.

24 Montgomery, G, Abt, G, Dobson, C, Smith, T., Ditroilo, M. Tibial impacts and muscle activation during walking, jogging and running when performed overground, and on motorised and non-motorised treadmills. Gait Posture.2016; 49:120-126.

25 Hamacher, D, Hamacher, D, Krowicki, M, Schega, L. Between-day test–retest reliability of gait variability in older individuals improves with a familiarization trial. Aging Clin Exp Res.2017;29:327-329.

26 Cudejko, T, Gardiner, J, Akpan, A, D’Août, K. Minimal shoes improve stability and mobility in persons with a history of falls. Sci Rep.2020; 10(1):1-10.

27 Petersen, E, Zech, A, Hamacher, D. Walking barefoot vs. with minimalist footwear–influence on gait in younger and older adults. BMC Geriatrics.2020;20(1):1-6.

28 Periyasamy, R, Anand, S, Ammini, AC. The effect of aging on the hardness of foot sole skin: a preliminary study.Foot.2012;22(2):95-99.

29 World Population Ageing 2019: Highlights. Available from: digitallibrary.un.org/record/3846855?ln=en&v=pdf.

30 Faul, F, Erdfelder, E, Lang, AG,Buchner, A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods.2007;39:175-191.

31 Orrell, A, Doherty, P, Miles, J, Lewin, R. Development and validation of a very brief questionnaire measure of physical activity in adults with coronary heart disease. Eur J Prev Cardiol.2007;14(5):615-623.

32 NHS;2021 Physical activity guidelines for older adults. Available from: https://www.nhs.uk/live-well/exercise/exercise-guidelines/physical-activity-guidelines-older-adults.

33 Davis, IS, Hollander, K, Lieberman, DE, Ridge, ST, Sacco, IC, Wearing, SC. Stepping back to minimal footwear: applications across the lifespan. Exerc Sport Sci Rev. 2021;49(4):228-243.

34 Hollander, K, Davis, IS. Chapter 39 - Minimal Shoes: Restoring Natural Running Mechanics in Foot and Ankle Biomechanics. In: WR, ST, editors. Academic Press;2023: 623-634.

35 Callisaya, ML, Blizzard, L, Schmidt, MD, McGinley, JL, Srikanth, VK. Ageing and gait variability—a population-based study of older people. Age Ageing.2010;39(2):191-197.

36 Menz, HB, Morris, ME, Lord, SR. Foot and ankle characteristics associated with impaired balance and functional ability in older people. J Gerontol A Biol Sci Med Sci.2005;60(12): 1546-1552.

37 Menz, HB, Sherrington, C. The footwear assessment form: a reliable clinical tool to assess footwear characteristics of relevance to postural stability in older adults. Clin Rehabil.2000;14(6):657-664.

38 Lindemann, U, Najafi, B, Zijlstra, W, Hauer, K, Muche, R, Becker, C, et al. Distance to achieve steady state walking speed in frail elderly persons. Gait Posture.2008;27(1):91-96.

39 Rydwik, E, Bergland, A, Forsen, L, Frändin, K. Investigation into the reliability and validity of the measurement of elderly people's clinical walking speed: a systematic review. Physiother Theory Pract.2012;28(3):238-256.

40 Hollman, JH, McDade, EM, Petersen, RC. Normative spatiotemporal gait parameters in older adults. Gait Posture.2011;34(1):111-118.

Section Editor comments:

Thank you for your helpful responses and revisions. There are two sentences that would benefit from revision to clarify the intended meaning.

Lines 124-124, “In addition, using a medical health questionnaire, completed prior to any testing.” This sentence is not complete. Is something missing?

Authors’ response: Thank you for your time and suggestions. This sentence has now been clarified in the submitted text. Please see page 5, lines 124 and 125.

Lines 230-232, “These were one participant’s thick condition due to loss of data during the collection process and two participants from the thin condition, because it was not possible to obtain at least 40 steps of steady gait to represent walking steadiness.” This sentence as currently written is not clear. Should it state something like this? “One participant with the thick footwear condition was excluded due to loss of data during the collection process, and two participants with the thin footwear condition were excluded because they were unable to complete at least 40 steps of steady gait.”

Authors’ response: This suggestion was very useful, thank you. It has been accepted and included in the document. Please see page 8, lines 231-234.

Reviewer 1 report:

Comments to authors

thank you for your revised work and the responses to the prior critiques. The manuscript is much clearer and will be useful to readers.

Authors’ response: Thank you so much for your time.

Reviewer 2 report:

Comments to authors

Thank you for addressing the concerns raised in my original review. All adjustments are satisfactory.

Authors’ response: Thank you so much for your time.

Table 1 Mean ± SD participant characteristics, including medical conditions reported by the participants.

Characteristic	Females	Males	Group
n	21	5	26
Age (years)	71.1 ± 4.5	70.6 ± 2.3	71.0 ± 4.1
Mass (kg)	68.4 ± 11.4	72.8 ± 9.7	69.2 ± 11.0
Height (cm)	164.5 ± 5.3	175.2 ± 7.8	166.6 ± 7.1
UK shoe size	6.0 ± 0.7	8.6 ± 0.9	Range = 5 to 10
Activity level	Active	Active	Active
Medical conditions			
Chronic obstructive pulmonary disease	-	*n* = 1	3.8%
Heart disease	*n* = 2	-	7.7%
High blood pressure	*n* = 5	*n* = 3	30.8%
High cholesterol	*n* = 2	-	7.7%
Osteoarthritis	*n* = 9	-	34.6%
Osteoporosis	*n* = 1	-	3.8%
Scoliosis	*n* = 1	-	3.8%

Footwear condition	Variable	Trial 1					Trial 2				
		0 to 40	40 to 80	80 to 120	120 to 160	160 to 200	200 to 240	240 to 280	280 to 320	320 to 360	360 to 400
Thick	Gait speed (m.s^{-1})	1.38 ± 0.14	1.38 ± 0.15	1.38 ± 0.13	1.38 ± 0.15	1.38 ± 0.14	1.40 ± 0.13	1.40 ± 0.14	1.40 ± 0.14	1.40 ± 0.13	1.40 ± 0.13
midsole	CV%	10.4%	10.9%	9.5%	10.6%	10.2%	9.5%	10.2%	10.1%	9.6%	9.4%
(*n*=25)	*n*	0	18	2	2	2	0	0	1	0	0
Moderate	Gait speed (m.s^{-1})	1.41 ± 0.17	1.41 ± 0.17	1.41 ± 0.16	1.41 ± 0.17	1.41 ± 0.16	1.44 ± 0.15	1.42 ± 0.15	1.42 ± 0.15	1.42 ± 0.15	1.42 ± 0.14
midsole	CV%	11.1%	12.2%	11.5%	11.9%	11.5%	10.7%	10.6%	10.5%	10.6%	9.7%
(*n*=26)	*n*	0	20	5	1	0	0	0	0	0	0
Thin	Gait speed (m.s^{-1})	1.43 ± 0.15	1.43 ± 0.15	1.43 ± 0.14	1.42 ± 0.14	1.41 ± 0.14	1.45 ± 0.15	1.43 ± 0.15	1.43 ± 0.15	1.43 ± 0.15	1.43 ± 0.13
midsole	CV%	10.6%	10.4%	10.1%	10.1%	9.1%	10.2%	10.4%	10.2%	10.3%	9.4%
(*n*=24)	*n*	0	20	2	0	0	2	0	0	0	0

Table 2 Mean ± SD gait speed (m.s^{-1}), coefficient of variation (CV%) and number of participants achieving familiarisation in each block of steps (*n*) for the three footwear conditions.