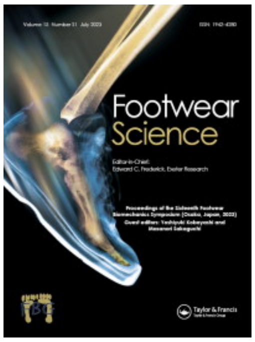

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Foot shape modelling of older adults with and without diabetes mellitus

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KEYWORDS Diabetes mellitus; foot shape; principal component analysis; diabetic neuropathy; foot ulcer; modeling; diabetes

Introduction

One of the primary reasons for foot ulcer formation, as a main risk factor for amputation in people with diabetes, is sustained high plantar pressures (PP) (Veves et al., 1992). The loss of sensation (diabetic neuropathy) associated with diabetes progression makes adequate footwear fit essential to redistribute high PPs and to eliminate high friction areas that would likely induce repetitive trauma. Furthermore, there is a need to establish a biomechanical definition for fit for people with diabetes and to determine if there are differences in foot shape between people with and without diabetes.

Purpose of the study

The aim was to create a foot shape model to determine the effect of diabetes and diabetic neuropathy on foot shape.

Methods

Fifty-eight participants between the ages of 50 and 88 (M/F: 26/32, 73 ± 8 years; 171 ± 9 cm; 80 ± 18 kg) with ($N_{DM} = 11$) and without ($N_{ND} = 47$) diabetes (type 2) were recruited. Five individuals with diabetes and nine without diabetes also reported having neuropathy. Participants who had no history of foot amputation and could stand (assisted if needed) for at least one minute were included. Each participant's foot was individually scanned while standing in the FootIn3D scanner (Elinvision, Lithuania) with equal weight distribution between feet for each scan. The study protocol was approved by the institutional human research ethics committee of the University of Queensland (2022/HE002010).

In the analysis, the left feet were mirrored to double the dataset for this explorative study. The 3D triangulated meshes were scaled and aligned according to established methods via an elastic matching algorithm and General Procrustes analysis (Schuster et al., 2021). Principal component analysis was performed to determine the major modes of shape variation, or principal components (PCs). A statistical shape model was created, and the cumulative eigenvalues were used to determine the proportion of the total shape variability explained by each PC (Schuster et al., 2021).

Results

The first PC represents the variations in foot and ankle width, arch height, toe shape (toward Egyptian or Greek), accounting for 29.5% of the variation (Figure 1). PC2 (16.6% of variation) characterizes the ab/adduction of the hallux (bunion formation) and second toe, heel-to-toe width ratio, ankle rotation and consequently, some medial

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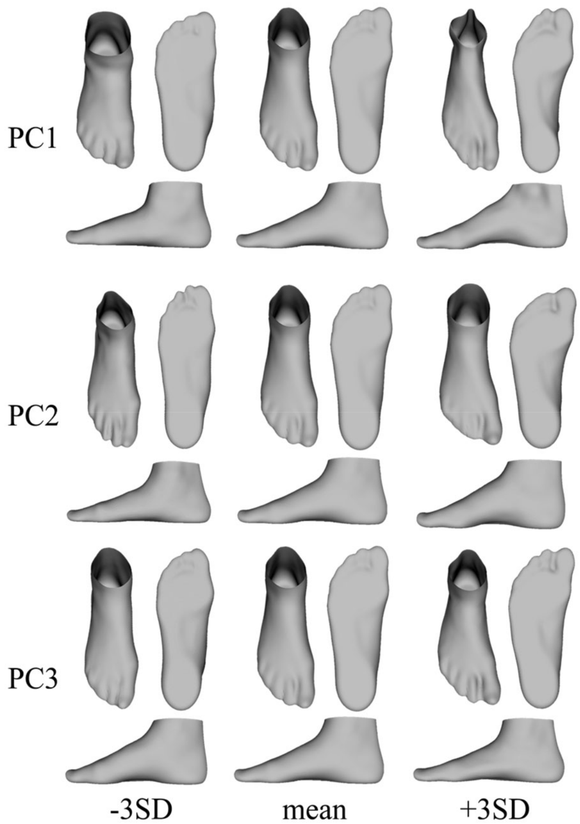

Figure 1. Visualization of the mean foot shape and ±3SDs of the first 3 PCs.

collapse of the longitudinal arch. The third PC (9.3% of variation) represents the ab/adduction of the hallux and forefoot/rearfoot alignment. Qualitative PC score cluster analysis showed there was no clear distinction between people with and without diabetes, nor for people with and without neuropathy.

Discussion and conclusion

In this study, a preliminary foot shape model for older adults with and without diabetes was created to determine the main foot shape variations: foot and ankle width, arch height, ankle rotation, the angles of the hallux and second toe, and heel-to-toe width ratio. The first three PCs accounted for over half of the shape variation (55.4%) which is consistent with previous work that considered young, healthy feet (Schuster et al., 2021).

Future work will expand the dataset with more (>45) foot scans of people with diabetes. This work has direct application for diabetic footwear design. Our team in Switzerland is developing intelligent footwear for people with diabetes (Pataky et al., 2016). The footwear will sense PP and then intelligently adjust the contour of the insole to ameliorate high PP areas. The foot shape derived from the presented and future research directly informs the shape changes necessary for the shoe last used to improve the potential fit of this footwear for people with diabetes. Furthermore, future extension of this dataset will provide a general foot shape model for therapeutic footwear designers.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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