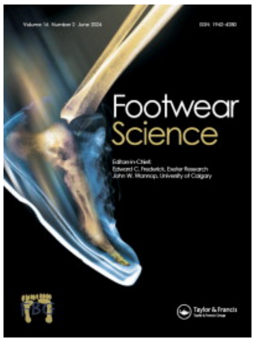

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RESEARCH ARTICLE

Does plantar pressure in short-term standing differ between modular insoles selected based upon preference or matched to self-reported foot shape?

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ABSTRACT

Prolonged workplace standing is commonplace and associated with a range of lower limb issues. Evaluating footwear interventions aiming to modify plantar pressure during standing is essential as the body is static, creating a different requirement for footwear. Previous research associates medial midfoot pressure with greater perceived comfort and identifies arch height as the most variable element of foot shape. Targeting footwear mass customization within this area may better address differences within the target wearers. This study aims to evaluate a modular insole system for its ability to modify plantar pressure during standing. Twenty-five participants completed a static and dynamic standing protocol for 60 seconds whilst measuring in-shoe peak and mean plantar pressure (KPa) and contact area (%). Individuals wore three insole options targeted towards different medial arch shapes (A– low arch, B– medium arch, C– high arch) and rated them for comfort. Participants received guidance to self-identify foot shape (low, medium, or high arch). Comparisons were drawn across the three insole profiles and between the insole rated as most comfortable (preferred), and the insole that matched the self-identified foot shape (matched). As insole arch height increased, medial midfoot pressure and contact area significantly increased, alongside significant reductions in first metatarsal pressure and contact. Preference was spread across insoles A, B, and C (56%, 32%, 12% of participants, respectively). Sixteen participants had different matched and preferred insoles, with significantly greater medial midfoot pressure and contact in the matched insole. The modular insole enabled different wear experiences, however, results suggest that individuals selected insoles lower than their foot shape. Providing adequate medial arch support enables redistribution of pressure which may enable greater comfort during the workday.

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Insole; modular; customization; plantar pressure; comfort

Introduction

Prolonged standing, defined as standing for at least 50% of the working day (Tomei et al., 1999) is common in manufacturing, retail, catering and assembly work. This is associated with high prevalence of back, leg, ankle and foot problems alongside pain and discomfort (Bernardes et al., 2023; King, 2002). Spending prolonged periods in static postures represents substantial exertions which increase forces applied to the musculoskeletal (MSK) system and are associated with high reported discomfort (Reid et al., 2010). Adjustments to the workplace environment are recommended to manage MSK complaints at work (The Prince's Responsible Business Network, 2019). Anti-fatigue mats are able to modify force applied to the foot, and have been recommended to manage risk associated with prolonged standing by the Health and Safety Executive (Health & Safety Executive, 2021). They have been identified to reduce plantar pressures in barefoot standing (Zhang et al., 2022) and reduce musculoskeletal discomfort in the lower limb and lower back (Speed et al., 2018). It is apparent that varying compression and thickness of the material impacts levels of reported comfort, however findings are inconclusive (King, 2002; Redfern & Chaffin, 1995). Two drawbacks are evident in flooring applications: firstly, it is not customizable and offers the same response for all workers, despite personal attributes which might alter their requirements. Secondly, flooring offers the opportunity to alter material, but not geometry, which has a role in redirecting forces, evident in the mechanism of orthotics for example (Bonanno et al., 2019).

Assessing footwear, or insoles, within relevant tasks is important considering (Kong & Bagdon, 2010) the differences in plantar pressure magnitude during walking and standing (Chatzistergos et al., 2017; Jonely et al., 2011). Pressure magnitudes are considerably higher during walking than standing in the hallux, medial forefoot, and medial heel (Jonely et al., 2011). Pressure magnitudes however did not differ between walking and standing within the medial arch, which recorded the lowest peak pressures across the foot in both tasks (Jonely et al., 2011). The importance of

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this foot region is amplified when considering the differences in plantar pressure characteristics between differently shaped feet (Periyasamy & Anand, 2013; Takata et al., 2021). Footwear with different arch profiles therefore offers clear potential for addressing pressure distribution during standing, and addressing individual foot shape that contributes to differences in plantar pressure (Jonely et al., 2011; Periyasamy & Anand, 2013; Takata et al., 2021). The requirement for choice is highlighted when insole choice has been previously assessed with preference shown towards both flat (Collins et al., 2017; Hatton et al., 2015; Mills et al., 2011) and contoured insoles (Lullini et al., 2020; Wang et al., 2020). Previous research has also identified changes in plantar pressure when wearing different insoles during standing (Anderson et al., 2020).therefore the potential to modify pressures.

Customization is designing or making changes to a product, so that it functions more specifically to the needs of an individual or task (Wang et al., 2016). Mass customization integrates the manufacturing efficiencies of mass production, whilst enabling more individually suited products to be produced (Piller & Müller, 2004). Footwear customization is achieved through 'style customization' (for aesthetic value), 'best-fit' (for comfort), or 'custom made' (for biomechanical effect) processes (Boer et al., 2004; Jovane et al., 2003). This could involve adaptation of the entire piece of footwear or producing an outer shell and modifying an orthotic or insole that sits within this shell.

As the medial arch is the most variable measure of foot shape (Stanković et al., 2018), and altering pressure in the medial midfoot can improve comfort (Caravaggi et al., 2016; Che et al., 1994; Jiang et al., 2021; Meng et al., 2020) with changes in insole geometry achieving this change in pressure (Mündermann et al., 2003). Customized 3D printed insoles have been demonstrated to reduce pain, discomfort and sensations of heavy legs in standing workers (Tarrade et al., 2019). The above factors all identify a mass customized footwear product targeted towards the medial arch not only addresses prevalent individual differences, but also leads to biomechanical changes beneficial to comfort, and the wearer's experience at work.

This however requires individuals to identify their own foot shape to make an informed selection within the mass customization offer. This has been identified to be relatively challenging with 48.9% of runners being able to achieve this (Hohmann et al., 2012) but 67.2% of athletes being unsure of their foot shape (Ramírez & Suárez-Reyes, 2022). However success has been seen within a population of standing workers with those identifying as having low arched feet trending towards lower foot posture index scores (FPI) (indicating low arch feet) than those self-identifying as having medium arch feet (Anderson et al., 2020). This study also identified that foot shape predisposed wearers to an arch material density preference (Anderson et al., 2020). Impact of insole shape was however not explored, for which manipulations in shape are commonplace within fully customized insole products. The combination of shape and material properties offers an opportunity to continue to develop footwear or insoles which are self-selected by wearers and specific to foot shape. Within a modular system where multiple footwear options are available to the wearer in one product, it is important for individuals to access the correct or recommended footwear condition to ensure they are wearing something suited to their needs.

Aims & hypothesis

The aim of the current study is to assess whether plantar pressure during short-term standing can be modified using a modular insole with different arch profiles, and to evaluate the design of the insole system based on plantar pressure differences. Further aims are to assess whether plantar pressures differ between insoles chosen by the individual based upon preference and insole profiles matched to self-reported foot shape. It is hypothesized that midfoot pressure characteristics will change across different arch profiles with pressure and contact increasing from low to high arch profile. Preference will be spread across arch profiles and the pressure differences cannot be hypothesized due to the uncertainty of individual insole selection.

Materials and methods

Participants

Twenty-five healthy participants (Male = 23, Female = 2; age = 30.8 ± 10.8 years; height = 1.80 ± 0.05 m; body mass = 83.0 ± 8.5 kg) were recruited from a convenience sample of the general population, due to impacts of Covid-19 restrictions participants could not be recruited from the population of target wearers who would be standing workers. Individuals were excluded from inclusion within the study if they had any injury that would impact their ability to stand for 1 hour, and if they had any conditions impacting plantar pressure distribution and magnitude. Participants gave written informed consent to participate in the data collection protocol approved by the University of Salford research ethics committee (reference HSR1920-029). Testing was completed outside of a laboratory environment in offices, homes and other areas with large flat surfaces.

Insoles

Insoles for testing comprised of 4 pieces made from blown polyurethane (PU) foam: main insole body which affixed with arch inserts like a jigsaw (Figure 1 b,c). Material properties and shape differed between arch inserts A, B, and C (Table 1). Shore densities were based upon previous work from WearerTech Ltd and The University of Salford (Anderson et al., 2020), and contouring was based on arch dimensions of standing workers collected from 3D scans. The insole set (insole body plus one arch insert) therefore allows for three different arch profiles. These were placed inside a shoe designed for use in standing occupational environments, the WearerTech Relieve shoes (Figure 1a) for all plantar pressure measurements as this is the shoe the modular insole is designed to be used within. Controlling footwear also reduces the impact of insole on fit of the footwear when potentially removing and replacing insoles from individual's own footwear, which may have a further impact on the comfort assessment and plantar pressure measurement.

Foot shape identification and insole preference

Participants were required to self-identify their foot shape prior to the commencement of testing. Participants were given outlines of 3 different foot shapes (Figure 2) described

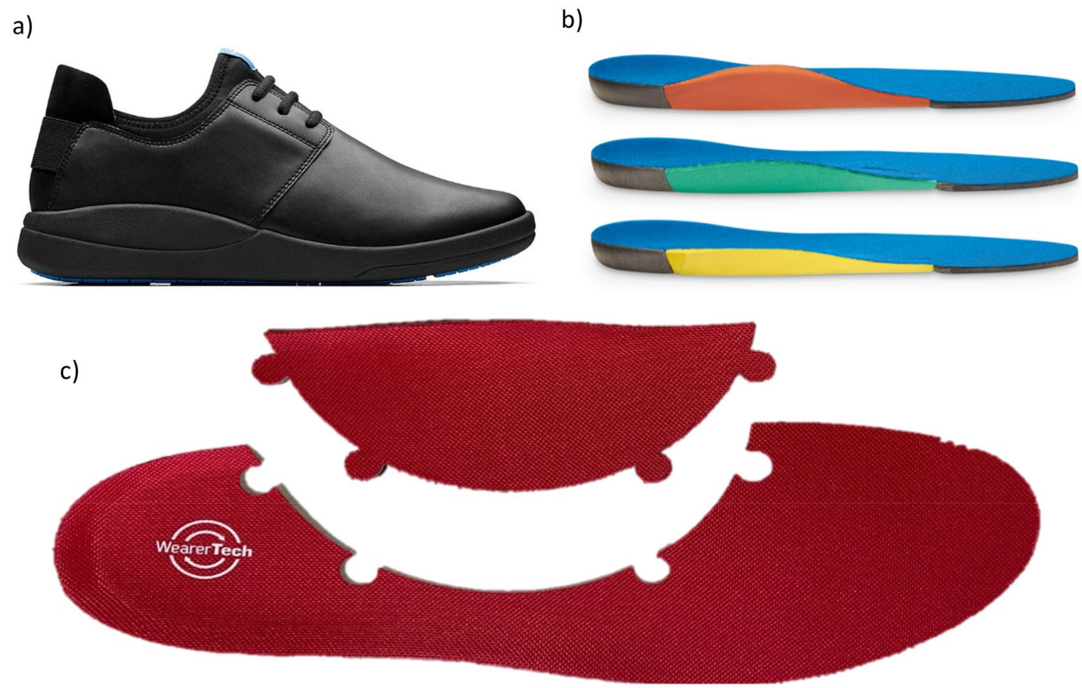

Figure 1. WearerTech Relieve shoe (a), insole A (yellow) insole B (green) insole C (red) insole profiles (b), jigsaw method for securing arch pieces to main insole body (c).

Table 1. Modular insole arch piece profiles and densities.

Insole	Colour (Figure 1)	Profile/contouring	Shore A density
A	Yellow	low	50
B	Green	medium	40
C	Red	high	30

as low, medium, and high arch and were asked to identify which was most similar to their own foot shape. This data was used to understand whether individuals preferred the insole profile that corresponded with their foot shape based on previous research by Anderson et al. (2020) who tested multiple insole combinations on wearers. For some participants the self-identified foot arch shape would be the same as the insole they identified (e.g. An individual identifying they had a low arch foot shape and selecting insole A as the most comfortable). When this did not match (e.g. An individual identifying they had a low arch foot and selecting insole C as most comfortable) comparisons were drawn between the insole participants rated as the most comfortable (preferred) and the insole that matched the participants self-reported foot shape (matched).

Plantar pressure

Plantar pressure was assessed using an instrumented in shoe pressure system (Pedar-X, Novel gmbh, Munich, Germany). Insoles of corresponding shoe sizes were inserted into both shoes and recorded data at 50 Hz. Participants completed 30 seconds of quiet standing and completed a dynamic standing task for 1 minute. Short durations of standing were assessed to understand how the modular insole design impacted pressure over the short term to inform design changes. The dynamic standing task was a tabletop sorting task to simulate the movement of standing workers, participants were required to sort coloured sticks from the middle of the table into their respective areas at six positions on the table surface. Order of arch insert was randomized for each participant and the testing protocol was completed for each participant and arch profile insole.

Plantar pressure data was analyzed using a custom-written MATLAB (MathWorks, Natick, Massachusetts, USA) code. The foot was split into 7 regions: Heel, lateral midfoot, medial midfoot, metatarsal head 1 (MH1), metatarsal head 3 (MH3), metatarsal head 5 (MH5), and toes based upon the sensor locations of the Pedar-X insole (Figure 3). For each region the following was calculated; mean peak pressure, mean pressure, and contact area. The 60-second protocol was broken into six 10 second periods. Peak pressure was defined as the maximum pressure in each area during each 10 second interval. This was then averaged across the standing protocol to give mean peak pressure. Mean pressure was defined as the mean of the pressure across the whole of a foot region across the whole of the standing protocol. The foot was deemed to be in contact with the Pedar insole sensor if the sensor recorded greater than 5 kPa. Sensors of the known area were then classed as in contact with the foot and therefore were totalled for each foot region. Contact area was then defined as a percentage of each foot region. Data from the left and right feet were combined to create one value per insole per participant for comparisons.

Comfort

Overall comfort of the insoles was analyzed on a 100 mm visual analogue scale (VAS) with anchors of Least comfort imaginable – Greatest comfort imaginable (Mündermann et al., 2002) immediately following the dynamic standing protocol. Participants marked the scale as they felt

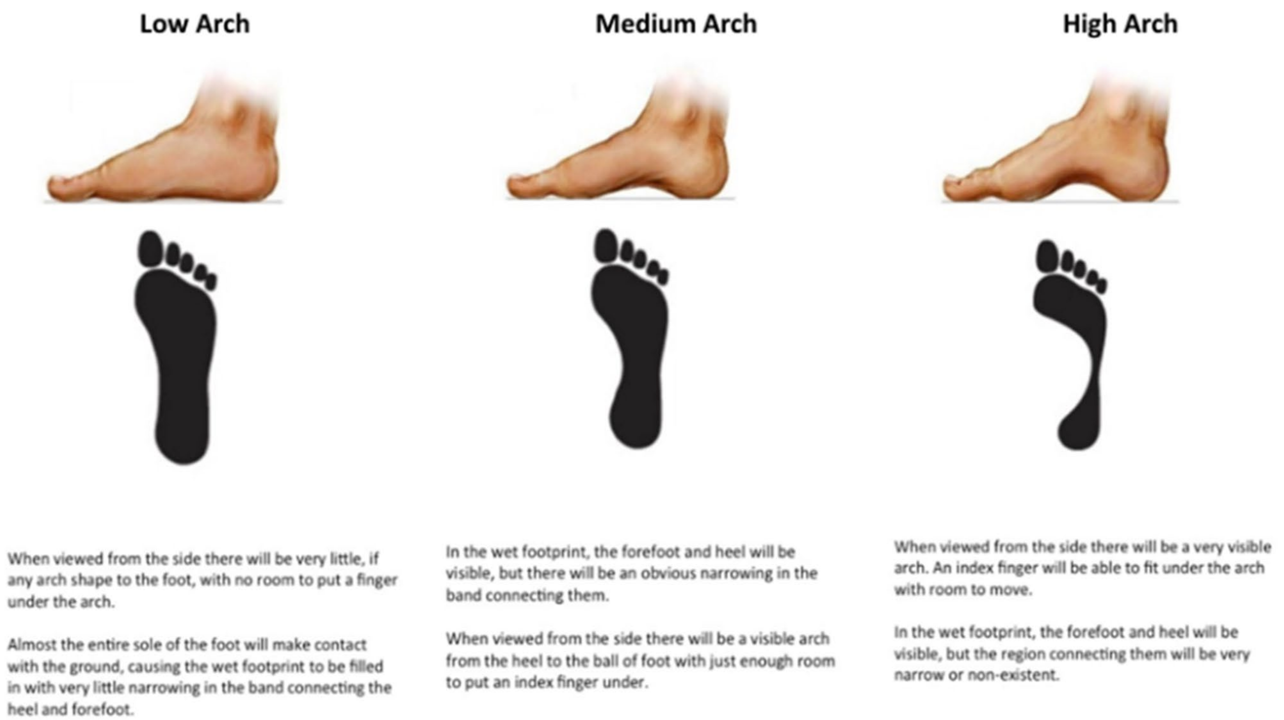

Figure 2. Guidance was given to participants to self-identify foot shape.

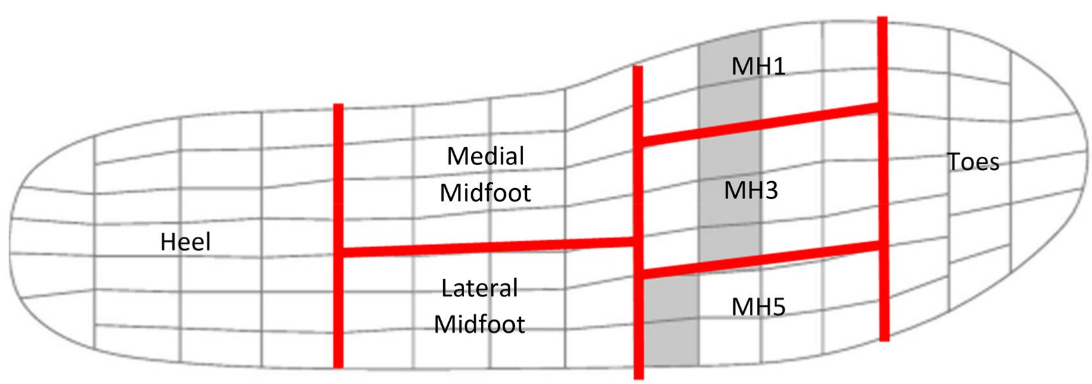

Figure 3. Pedar-X insole outline with seven regions defined.

appropriate. Participants were also given a generic foot outline to indicate areas of discomfort they felt whilst wearing each test insole. After wearing all three insoles participants ranked each insole from 1 (most comfortable) to 3 (least comfortable).

Statistics

SPSS statistics 26 (IBM, New York, USA) was used to conduct all statistical analysis. Pressure and comfort data was tested for normality using the Shapiro-wilk test and assessed for significant outliers using box plots. Due to the presence of non-normally distributed data sets with outliers present, plantar pressure and comfort data from the VAS was assessed for difference using the non-parametric Friedman test with a Bonferroni correction for multiple comparisons. For comparisons of preferred and matched insoles data was again checked for normality using a shapiro-wilk test, and for significant outliers using box plots. There were instances of non-normally distributed data and significant outliers, therefore data was compared using a Wilcoxon signed rank test to determine statistical differences between preferred and matched conditions. A Friedman test was used to compare ranked data for insole preference. A p value of 0.05 was selected to denote significance across all tests which was corrected for multiple comparisons using a Bonferroni method. Three comparisons were being made (A – B, A – C, B – C), the p-value of 0.05 was therefore divided by 3 to give a level of significance of $p \leq 0.017$.

Results

Plantar pressure

During static standing there was significantly greater medial midfoot peak pressure, mean pressure, and contact area in the C insole than in the B and A conditions. There was also significantly lower mean pressure and contact area in

MH1 in the C compared to B insole. Mean pressure at MH3 was significantly lower in the C insole compared to the B insole, and contact was significantly lower in the C compared to the A insole in this area of the foot.

During dynamic standing mean pressure and contact area were significantly greater in the midfoot whilst wearing the C insole compared to the A and B insoles. In the MH1 region peak and mean pressure was significantly greater in the C compared to the B and A insoles. Contact area was significantly lower in the C insole compared to the B. Mean pressure and contact area was significantly lower in MH3 when wearing the C compared to the A insole.

Ranking

There was overall significant difference for the ranking of insoles by preference (Table 2, $p = 0.001$). The C insole was significantly the least preferred when compared to the A (b, $p = 0.001$) and the B (c, $p = 0.049$) insoles, there was no significant difference between the A and B insoles ($p = 0.774$). There was overall significant difference (p=.005) between the insoles for comfort perception on the visual analogue scale, the A insole was significantly more comfortable than the C insoles ($p = 0.006$), with no significant difference in perceived comfort between the A and B ($p = 1.000$) and B and C insoles ($p = 0.085$) (Table 3).

Preferred v matched

Nine participants selected the insole that matched their self-identified foot shape as being the most comfortable, therefore comparisons have been made for the 16 participants where the matched and preferred condition was not the same.

In dynamic standing there was significantly greater mean pressure, and contact area in the medial midfoot when wearing the insole that was matched to foot shape compared to the insole that was chosen as most comfortable (preferred). However, during static standing there was no significant differences in peak or mean pressure or contact area between the shape matched insoles, and the insole selected as the most comfortable (Table 4).

Discussion

The current results demonstrate the ability for a modular insole system with different arch profile and hardness combinations to alter the plantar pressure during standing. The C insole increased pressure and contact in the medial midfoot when compared to the A and B insoles. This subsequently reduced contact and pressure under the forefoot, specifically MH1 and MH3. When comparing matched and preferred insole conditions, 9 participants identified the insole that matched their foot shape as the most comfortable, leaving a disparity between preferred and matched condition for 16 of the participants. These individuals chose the insole with lower mean pressure and contact area in the medial midfoot during dynamic standing as most comfortable.

Table 2. Plantar pressure data during static and dynamic standing for all foot locations in each insole condition, data presented as median (IQR). Significance set at $P \leq 0.05$ (bonferroni post hoc $p \leq 0.017$).

		Static standing task							Dynamic standing task						
		Heel	LM	MM	MH1	MH3	MH5	Toes	Heel	LM	MM	MH1	MH3	MH5	Toes
Peak Pressure (Kpa)	A	99.6 (29.0)	71.0 (23.7)	37.5 (13.8)^{*b}	60.0 (23.5)	52.3 (16.7)	69.6 (23.3)	74.0 (40.6)	90.2 (36.0)	88.1 (31.0)	52.1 (26.5)	78.1 (28.5)^{*b}	68.1 (22.7)	80 (21.9)	93.1 (27.7)
	B	97.1 (28.7)	71.5 (22.3)	39.0 (15.0)^{*c}	63.5 (28.5)	50.8 (11.5)	62.1 (29.8)	72.5 (42.1)	90.4 (32.1)	91.5 (34.6)	49.0 (29.0)	73.8 (32.1)^{*c}	65.8 (18.3)	82.7 (23.3)	88.1 (35.6)
	C	94.6 (30.4)	74.2 (25.4)	43.1 (12.5)^{*bc}	57.9 (30.4)	55.0 (16.0)	70.2 (21.9)	72.9 (37.7)	90.2 (43.1)	92.1 (35)	52.1 (23.1)	68.3 (21.0)^{*bc}	67.7 (24.2)	83.3 (30)	99.0 (27.1)
Mean Pressure (Kpa)	A	38.1 (7.3)	38.4 (8.8)	6.6 (7.5)^{*b}	20.8 (11.8)	20.2 (9.0)	24.4 (9.3)	13.9 (9.0)	30.3 (11.0)	40.6 (11.1)	6.6 (10.5)^{*b}	27.4 (8.5)^{*b}	26.9 (9.6)^{*b}	27.5 (12.4)	16.8 (7.1)
	B	36.4 (8.6)	35.3 (9.1)	10.2 (8.4)^{*c}	19.7 (11.8)^{*c}	18.9 (9.9)^{*c}	24.9 (11.6)	14.9 (5.1)	31.6 (13.5)	40.1 (13.1)	10.6 (11.3)^{*c}	24.2 (9.5)^{c}	22.4 (11.7)	30.1 (9.3)	18.0 (6.0)
	C	37.3 (8.1)	37.9 (12.7)	10.1 (6.5)^{*bc}	18.0 (12.4)^{*c}	19.5 (10.0)^{*c}	26.7 (11.0)	13.0 (10.1)	31.3 (12.1)	41.4 (11.7)	13.2 (14.0)^{*bc}	19.0 (11.9)^{*bc}	22.5 (11.1)^{*b}	29.0 (9.2)	20.0 (6.5)
Contact (%)	A	84.7 (6.8)	96.6 (9.8)	25.9 (32.3)^{*b}	62.7 (34.0)	71.2 (18.6)^{*b}	62.1 (18.3)	36.6 (20.7)	73.0 (11.9)	92.4 (12.2)	24.4 (32.0)^{*b}	65.2 (24.0)	72.4 (26.8)^{*b}	66.6 (16.9)	44.9 (15.3)
	B	84.4 (7.2)	98.4 (11.0)	45.7 (34.4)^{*c}	63.4 (18.8)^{*c}	67.9 (20.4)	62.2 (26.9)	41.0 (25.1)	74.2 (9.7)	93.1 (17.2)	39.9 (36.0)^{*c}	65.6 (17.7)^{*c}	71.8 (22.2)	69.7 (23.0)	50.2 (19.5)
	C	84.9 (9.6)	95.4 (9.4)	52.0 (33.1)^{*bc}	59.4 (28.0)^{*c}	66.4 (23.4)^{*b}	60.6 (26.2)	36.5 (26.9)	74.1 (11.4)	88.6 (13.5)	47.9 (36.4)^{*bc}	56.1 (21.9)^{*c}	61.0 (28.4)^{*b}	66.2 (24.7)	45.4 (16.1)

Indicates significant difference between conditions (a: A v B, b: A v C, c: B v C).

Table 3. Participant self-identified foot shape, insole ranking frequencies and comfort data from visual analogue scale (VAS).

Foot arch shape	Participants identifying as foot arch shape	Insole	Ranking frequency			VAS median (IQR)
			First/ Most preferred	Second	Third/ Least preferred	Overall Comfort
Low	6 participants	A	14	8	3*b	78 (40)*b
Medium	15 participants	B	8	12	5*c	67 (23)
High	4 participants	C	3	5	17*b,c	48 (36.5)*b

*Significance set at $p < 0.05$. *Indicates significant difference between conditions (a: A v B, b: A v C, c: B v C).*

Table 4. Plantar pressure data during static and dynamic standing for all foot locations in chosen and matched insoles, data presented as Median (IQR). Significance set at $p < 0.05$.

		Static standing task							Dynamic standing task						
		Heel	LM	MM	MH1	MH3	MH5	Toes	Heel	LM	MM	MH1	MH3	MH5	Toes
Peak Pressure (Kpa)	Preferred	92.6 (27.9)	72.2 (29.4)	38.2 (12.8)	60.1 (34.7)	53.4 (16.3)	69.7 (19.3)	73.2 (45.9)	91.1 (41.8)	91.7 (26.8)	52.3 (25.1)	70.0 (33.9)	68.5 (17.3)	79.5 (16.1)	91.1 (28.7)
	Matched	83.3 (24.6)	75.2 (22.3)	36.9 (14.7)	65.0 (45.0)	55.4 (14.2)	59.6 (26.8)	78.9 (43.9)	84.2 (27.1)	91.6 (27.0)	42.9 (23.4)	70.8 (27.4)	62.9 (19.5)	82.4 (31.8)	92.7 (31.9)
Mean Pressure (Kpa)	Preferred	36.1 (6.8)	35.7 (10.5)	7.1 (9.3)	19.2 (11.4)	23.8 (9.9)	25.9 (9.3)	15.9 (7.8)	32.3 (11.4)	40.4 (10.6)	7.6 (10.6)*	23.1 (14.2)	28.1 (11.3)	28.0 (12.5)	18.7 (9.1)
	Matched	36.6 (8.2)	39.5 (10.9)	10.2 (10.2)	21.7 (14.4)	22.6 (10.8)	25.0 (10.7)	14.5 (9.4)	27.4 (14.7)	41.9 (10.7)	9.8 (10.3)*	23.9 (9.5)	25.9 (9.9)	30.8 (10.6)	19.5 (8.7)
Contact (%)	Preferred	82.5 (8.8)	97.5 (13.5)	32.1 (43.3)	61.3 (32.5)	72.7 (11.9)	62.2 (20.1)	44.0 (17.6)	73.9 (10.1)	92.2 (14.4)	29.6 (44.9)*	66.6 (31.4)	75.5 (25.3)	65.5 (19.3)	51.1 (16.4)
	Matched	84.7 (7.0)	94.8 (7.4)	39.3 (34.9)	59.8 (23.5)	71.7 (10.7)	63.7 (18.5)	41.0 (20.6)	74.2 (14.1)	89.6 (13.1)	35.4 (35.3)*	62.4 (20.3)	72.4 (24.0)	68.0 (17.3)	50.2 (24.8)

**Indicates significant difference between conditions.*

There was a spread of preferences across the 3 arch inserts. 56% of participants selected the A insole as the most comfortable, 32% of participants selected the B, and 12% the C insole. This range of preference demonstrates a requirement for some offer of choice and mass-customization to better fit the footwear needs of a population. Due to the nature of the customization offering, an unequal split of preferences was expected as the spread of plantar foot shapes is not equal in the general population (Stanković et al., 2018; Xiong et al., 2010), or within the self-identified foot shapes from the current study. Individuals may also value different aspects of the footwear, with some preferring greater support and therefore more contoured insoles, or less invasive footwear and therefore flatter insoles, which may skew the spread of preferences across the insoles within the study.

Plantar pressure results from the current study identified that the insole conditions could modify pressure and contact area in short-term static and dynamic standing tasks in some foot regions. During short-term static standing there was significantly greater medial midfoot peak pressure, mean pressure, and contact area in the C insole than in the B and A conditions. Modification of contouring of the medial arch has previously increased medial midfoot pressure and contact area in walking (Bousie et al., 2013; Che et al., 1994) Similarly, mean pressures in the forefoot were also modified by insole C in MH1 and MH3; lower than in insole B. This occurred as arch height increased, which has also been observed in assessments of insoles during walking (Redmond et al., 2009). Pressure and contact areas in the heel, lateral midfoot, toes and MH5 did not differ significantly across the 3 insole conditions. The dynamic standing task produced similar results as the static standing task in the medial midfoot, reducing pressure and increasing contact area. The short duration of standing assessed during the current investigation allowed insight into the short-term performance of the insole, and how pressure was impacted. The reality of the footwear usage is that it will be used by individuals standing for 8-12 hours each day (Anderson et al., 2019), longer pressure data collections allude to minimal changes in pressure parameters after 3 hours of continuous standing (Anderson et al., 2018). In walking, footwear comfort has previously been linked to increased pressure in the medial midfoot (Che et al., 1994) and increases in medial midfoot contact (Bousie et al., 2013), whereby both factors would be achieved by increasing the contouring underneath the medial arch. Plantar pressure results from the current study, during standing and dynamic standing, show significant increases in medial midfoot pressure when the insole arch profile increases, however this insole was deemed as the least comfortable.

Only nine participants identified the insole profile that matched their foot shape, therefore the preferred (based on most comfortable) insole and matched (based on perceived foot shape) were not the same for 16 participants. This disparity could be related to the premise of matching a foot to an insole being inappropriate or the matching of the foot and insole being unsuccessful. In terms of the former: Variations in plantar foot shape create different (Periyasamy & Anand, 2013), preferences for contoured orthoses which increase contact area in the medial midfoot in walking are well-reported (Caravaggi et al., 2016; Meng et al., 2020; Mündermann et al., 2003). It could be that this relationship, previously been identified in walking, does not translate to standing tasks. In terms of the latter: the inability for around half of a group of individuals to accurately identify their own foot shape has been shown within previous research (Hohmann et al., 2012; Ramírez & Suárez-Reyes, 2022). To overcome this, adding a preference for 'feel' in terms of material hardness increases number of 'correct' recommendations to 2/3 of participants selecting the insole matched to their foot shape and material preference as most comfortable (Anderson et al., 2020). Exploring this latter point further, considering the group level, there were limited differences between preferred and matched insoles with significantly larger mean pressure and contact area in the medial midfoot whilst wearing the matched insole. This could be an impact of an averaging effect, where individuals with medium arched feet may have selected either insole A or C as most comfortable.

Individuals who stand for work have previously defined a perceived benefit of 'supportive' footwear (Anderson et al., 2017), which may be a function of symptomatic feet due to long-term standing at work, which would not have been replicated in our participants. Pain or discomfort within the foot are factors that are considered when selecting footwear (McRitchie et al., 2018; Menz, 2016). Pain in the lower extremity/foot (1.7 fold) is highly prevalent in those who stand for at least half of their working day and around 1 in 4 chefs (23%) and nursing assistants (26%) report continued pain in the hip, knee and foot after a 2 year period (Andersen et al., 2007). If an individual with a low arched foot and forefoot pain were able to tolerate the increased pressure within the midfoot a high arched insole would provide, this would enable them to have some pressure relief within the forefoot to reduce feelings of pain or discomfort. Similarly with selection of a flatter insole would avoid high pressures in the medial midfoot, this may be related to the medial midfoot being the most sensitive area of the foot (Messing & Kilbom, 2001) indicating that there is potential for an acceptable pressure range in the medial midfoot for comfort. Regarding the standing workforce there are many complications prolonged standing causes (King, 2002; Reid et al., 2010) with a large percentage of individuals within this workforce experiencing pain (Andersen et al., 2007). Footwear is a mechanism in which these factors can be addressed (King, 2002; Redfern & Chaffin, 1995), therefore exploring the insole functioning in a standing workforce specifically would help make further adaptations to support comfort increases in this population and task.

Some limitations have already been highlighted, influenced by associated Covid-19 closures of workplaces, this work was undertaken on adults who were not standing workers in mocked-up workplace standing tasks. Therefore adaptations that may be present in these long-term workers (Anderson et al., 2018, 2020) were likely not in our population and the wear period was short-term (60 seconds) compared to standing for a full day. A further limitation of the current study is the absence of an objective measurement of foot shape, without this, it cannot be determined whether the self-identified foot shape reflects the actual foot shape of the participants. However, this highlights that in the case of retail purchase of footwear and insoles where multiple product options are available with no available foot shape measurement tool, the buyer is ultimately responsible for the identification of their own foot shape and the needs associated with that. From current results, there is a large mismatch between the self-identified foot shape and the predicted most comfortable insole profile. Providing multiple footwear options within a single product, as is the case with the modular insole in the current research, the results demonstrate a requirement for education of the consumer regarding ways in which they can accurately identify their own foot shape, and the subsequent benefits of an insole product that matches this. If education is not feasible, then more modular offerings should be available for individuals to make informed choices surrounding insole profiles by being able to test multiple profiles within one product, and being able to select their favoured configuration.

Conclusion

Results from the current investigation show that increasing arch heights enables increases in pressure and contact in the medial midfoot, this in turn reduced pressure in the medial forefoot. Fourteen of the 25 (56%) of the wearers preferred the A insole and preference only matched predicted preference from foot shape for 9/25 (36%) of participants. This shows that matching foot shape to insole shape may not be a suitable way to recommend footwear for comfort for all wearers during standing. Further research could explore reasons for this to help provide further customization selections based on additional variables and within-standing workers during long-term standing.

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