The Effectiveness of Felt in Reducing Peak Plantar Pressures at the 1st Metatarsophalangeal Joint: In a Healthy Population

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Research

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Abstract

Semi-compressed felt is frequently used in clinical podiatric practice to offload areas of high pressure, particularly in patients with chronic ulceration. The study aimed to assess the effectiveness of semi-compressed felt, on plantar pressures, in offloading the 1st metatarsophalangeal joint, whilst assessing pressure encountered at the peripheries. Elevated plantar pressures are a strong predictor of ulceration in patients with diabetic foot disease, where undetected mechanical trauma can rapidly become ulcerative. In this study, plantar pressure was assessed using the Foot Work Pro plate (AM CUBE, Inc., France, www.amcube.net), in three conditions: barefoot; 5mm thickness and 10mm thickness conditions. This study was of a cross sectional design, where participants were conveniently sampled within the Podiatric Medicine student population within the National University of Ireland, Galway. 33 participants (28 females; 5 males) with a mean age of 23 years (Interquartile Range, 18-44). Plantar pressures at the 1st metatarsophalangeal joint decreased ($P < 0.01$; $P < 0.01$), when semi-compressed felt was applied to offload the 1st metatarsophalangeal joint. Whereas, plantar pressures were found to be increased at both the 3rd metatarsophalangeal joint ($P = 0.04$; $P = 0.01$) and the 5th metatarsophalangeal joint ($P = 0.82$; $P = 0.40$), as a result of applying felt to the 1st metatarsophalangeal joint. Evidently, offloading one joint subjected other joints to greater mechanical load allowing insight into the mechanical redistribution associated with the use of felt in offloading, which must be accounted for in the high risk diabetic foot.

Background

Hyperkeratotic lesions are a result of thickening of the stratum corneum of the epidermis caused by cellular hypertrophy (1), predominately due to abnormal mechanical stresses, often resulting in elevated plantar pressures (2, 3). Such mechanical stresses are resultant of a combination of intrinsic and extrinsic factors: for example biomechanical factors; footwear and activity levels (4). As the epidermis thickens, both stress and pressure increase at vulnerable sites of the foot (5).

Within podiatric practice, advancing age can contribute to an increased risk of both hyperkeratosis and ulceration. Changes associated with ageing include: thinning of the epidermis and dermis; decreased subcutaneous fat; atrophy of microvasculature; reduced sebum production and secretion; and reduced sensation (6). Therefore, it must be noted that offloading is essential to help reduce and redistribute pathological pressures, especially in patients living with chronic conditions such as diabetes (7, 8). Offloading sites exposed to high pressure is essential in the healing of active ulceration and in reducing the risk of amputation in those at risk (9).

Plantar pressure assessment actively demonstrates the effect that kinematic changes, within joint complexes, has on surrounding tissues as a vertical force (10). Clinically, studies have found an a correlation between plantar pressure patterns and various pathological conditions such as posterior tibial tendon dysfunction (11), medial midfoot arthritis (12), rheumatoid arthritis (13) and diabetes (14). Generally, normative dynamic values fall in the region of 200–500 kPa, which is comparative to those with diabetic neuropathy, where values from 1000–3000 kilopascals (kPa) have been recorded (15). Although the relationship between ulceration and plantar pressures remains ambiguous, excess pressure caused by

lesions or deformity can inhibit tissue regeneration, and the cumulative effect can eventually lead to tissue breakdown and ulceration (16). Similarly, foot deformity, such as prominent metatarsal heads and lesser toe deformities, has been found to have a significant relationship with ulceration (17). In a diabetic neuropathic population, peak pressures were 1.7 times higher in studied subjects with lesser toe deformities when compared to those without deformity (18).

For individuals living with chronic disease, offloading with semi-compressed felt (SCF) is a vital in the reduction and redistribution of pathological pressures. Offloading sites of high pressure is essential in the healing of active ulceration and in reducing the risk of amputation in those at risk (9). Advantages include affordability, accessibility, and ease of use. It is recognised as an easily customised 'chairside' modality of offloading in clinical practice (19). While anecdotally, SCF is regularly used as an off-loading modality; it is important that its efficacy is investigated; and the effect that thickness of SCF application has on plantar pressure measurements.

The primary aim of this study was to investigate:

1. the effectiveness of a SCF cut-out in reducing peak plantar pressures at the 1st metatarsophalangeal joint (MTPJ) under two conditions: 1)5mm thickness 2)10mm thickness.

The secondary aim of this study was to investigate:

1. the effect of a SCF felt cut-out, offloading the 1st MTPJ, on the peak plantar pressures at the 3rd MTPJ and the 5th MTPJ.

Patients/materials And Methods

This study utilised a cross-sectional and same-subject design involving a healthy population of NUIG Podiatric Medicine students. The primary aim of this study was: to investigate the effectiveness of a 5mm SCF plantar metatarsal pad (PMP); and a 10mm SCF PMP in reducing peak plantar pressures at the 1st MTPJ. The secondary aim of this study was to investigate: the effect on peak plantar pressures at the 3rd MTPJ and the 5th MTPJ during offloading of the 1st MTPJ

Ethical approval was granted from the National University of Ireland Galway (NUIG) College of Medicine, Nursing and Health Sciences Research Ethics Committee, and the study was conducted in accordance with the principles of the Declaration of Helsinki.

Participants were recruited by means of convenience sampling. Administrative staff in the Discipline of Podiatric Medicine acted as gatekeeper to the research and distributed study information and consent materials via University email addresses to all undergraduate students enrolled on the BSc (Hons) Podiatric Medicine programme. Interested participants were invited to contact the lead researcher via email if they were interested in further information regarding participation in the study.

Inclusion & Exclusion Criteria

Data collection was conducted on a ‘healthy’ student population. ‘Healthy’ was defined as having an ability to ambulate without aid whilst having no significant vascular, neurological or orthopedic impairment. Participants were included if they were: 18 years of age and older; and had the ability to ambulate independently of assistance. A total of 33 participants were included in the study. Informed written consent was obtained prior to entry into the study, and each participant was required to attend for one single data collection appointment.

The following anthropometric and demographical data were recorded; age, gender, height, weight, body mass index (BMI). Foot posture was classified according to the Foot Posture Index (FPI) (20). Bony landmarks were identified on the plantar aspect of both feet to facilitate standardised application of SCF padding (Figure 1).

Table 1: Conditions and anatomical location assessed

Conditions and anatomical location assessed			
Joint	1 st MTPJ	3 rd MTPJ	5 th MTPJ
Conditions			
0mm (Barefoot)	0mm 1 st MTPJ	0mm 3 rd MTPJ	0mm 5 th MTPJ
5mm	5mm 1 st MTPJ	5mm 3 rd MTPJ	5mm 5 th MTPJ
10mm	10mm 1 st MTPJ	10mm 3 rd MTPJ	10mm 5 th MTPJ

A 5mm SCF (Hapla; Cuxson Gerrard & Co. Ltd., United Kingdom), PMP with an aperture cut out to the 1st MTPJ was designed, whereby standardised dimensions were used (21). Self-adhesive hypoallergenic tape (Hypafix, BSN Medical, Hamburg, Germany) was used to secure the padding to minimise movement of the PMP. To ensure uniformity, all padding was constructed by the principal investigator adhering to these specifications.

Peak Plantar Pressures were collected using the Foot Work Pro plate (AM CUBE, Inc., France, www.amcube.net). Data were analysed using the Foot Work Pro software, version 3.2.0.1 (IST Informatique – Intelligence Service et Technique, France. Software calculated the peak pressure of each region of the foot, according to the software’s masking system, in the unit KiloPascal (KPa). A separate reading was recorded for the 1st MTPJ, 3rd MTPJ and 5th MTPJ was obtained for each condition.

A two-step protocol to collect plantar pressures was utilised (18, 22). Participants were instructed to start walking in a particular sequence: by stepping initially with one foot on the ground; taking the next step on the pressure plate; and walking a further 3 steps. This was to ensure a standardised procedure and to avoid direct targeting of the pressure plate. Participants were instructed to walk across the walkway with their head up and looking straight ahead to further avoid targeting (Richards, 2018). Participants were allowed a period of acclimatisation with the equipment prior to data collection. Five measurements were taken per

foot per condition, whereby the 1st and the 5th reading were discarded (Lavery *et al.*, 1997; Gatt *et al.*, 2016). An average was calculated from the 2nd, 3rd and 4th reading for each condition (Table 1).

The three conditions analysed are described in Table 1. Each participant received a non-identifiable code upon entry of the study. The unprocessed data were coded and entered using Microsoft Office Excel 2010 on site. Only the coded data was extracted and analysed using SPSS statistical package (Version 25).

Statistical methods

Descriptive statistics were obtained from each variable presented as the mean $\pm$ standard deviation. Q-Q plots identified that the data set was not normally distributed, allowing for non-parametric tests to be used for analysis for FPI and plantar pressures. Inferential statistics in the form of Shapiro-Wilk Test for normality was used for the variables: age, gender, height, weight, BMI and FPI. Whereas, Kolmogorov Smirnov test was used for plantar pressure data.

Wilcoxon Signed Rank test was performed, due to the non-parametric nature of the data. Analysis was performed between the plantar pressure intervals at the 1st, 3rd and 5th MTPJ, where the paired parameters included: 0mm (Barefoot) vs. 5mm; 0mm (Barefoot) vs 10mm; and 5mm vs.10mm.

Results

The total sample size consisted of 33 volunteers (28 females; 5 males) with a mean age of 23 years (range, 18-44). The mean recorded BMI was 23.96 ± 5.53 , with a range of 16.98 – 39.96 Kg/cm². The median BMI was 23.06. In terms of FPI, the mean foot posture was 2.64 ± 2.28 .

Table 2: Participant Demographics

	Age (Years)	Gender	Height (M)	Weight (Kg)	BMI (Kg/cm ²)	FPI
N	33	33	33	33	33	66
Mean	22.9 $\pm$ 5.02	.9 $\pm$.4	1.7 $\pm$.1	71.2 $\pm$ 18.7	23.9 $\pm$ 5.5	2.6 $\pm$ 2.3
$\pm$ Standard Deviation						
Range	26	1	.50	82	23.0	9
Minimum	18	0	1.52	48	17.0	-2
Maximum	44	1	2.02	130	40.0	7

Table 3: Test Statistics

Test Statistics ^a									
	1st met 5mm - 1st met 0mm	1st met 10mm - 1st met 0mm	1st met 10mm - 1st met 5mm	3rd met 5mm - 3rd met 0mm	3rd met 10mm - 3rd met 0mm	3rd met 10mm - 3rd met 5mm	5th met 5mm - 5th met 0mm	5th met 10mm - 5th met 0mm	5th met 10mm - 5th met 5mm
Z	-3.067 ^b	-5.235 ^b	-4.236 ^b	-2.019 ^c	-2.552 ^c	-.901 ^c	-.231 ^b	-.866 ^c	-1.674 ^c
Asymp. Sig. (2-tailed)	.002	<.001	<.001	.044	.011	.368	.818	.387	.094
a. Wilcoxon Signed Ranks Test; b. Based on positive ranks.; c. Based on negative ranks.									
Mean % Change	-4.21	-19.76	-11.96	+5.16	+8.21	+4.13	+9.30	+19.76	+13.04

Wilcoxon Signed Ranks Test results indicated a significant ($P < .05$) reduction in pressure in all three conditions at the 1st MTPJ, as demonstrated in Table 3. Overall, mean percentage changes in plantar pressure demonstrated offloading of the 1st MTPJ, with unloading on the 3rd and 5th MTPJs respectively. Summarised below, in Fig 2, is the trend in plantar pressure when SCF is applied to offload the 1st MTPJ.

Discussion

Results indicated that a SCF PMP offloads the 1st MTPJ by 4.2% when 5mm is applied to offload, whereas SCF offloads the 1st by 19.76% when 10mm was used. Although both were statistically significant, it was evident that 10mm was more effective in reducing PPs at the 1st ($P < .001$) when applied to offload the 1st MTPJ. This contrasts with other studies that observed a significant decrease in plantar pressure when 5mm was applied to offload the 1st MTPJ, ranging from 23.9% – 31.48% (23); and similarly when 7mm was applied to offload the 2nd MTPJ, 25% (24). Although it must be acknowledged that different measurement systems were used. Interestingly, it was shown in this current study that the peripheries experienced excess pressure applied upon increase of offloading material to the joint of interest. This phenomenon relates to the ‘edge effect’ introduced previously whereby an increase in pressure was observed at the immediate peripheries of the padding (25). However, in this current study the surrounding joints were studied. Therefore, demonstrating the potentially detrimental effect padding can have in a high-risk pathological foot.

The current study was subject to limitations. The chosen ‘healthy’ cohort was based on the exclusion of vascular, neurological or orthopaedic impairment to allow for a homogenous sample. The sample consisted of a female majority (28 female; 5 male) and it is possible that this may have introduced a form of gender bias which is often the case in a healthcare educational setting (27). Gender imbalance can also be a common consequence of convenience sampling in a healthcare cohort, as recruitment is based on accessibility, availability, and ease of access (28).

Although limb dominance was not recorded in this study, it has been demonstrated that the dominant leg takes an increased load (29), which must be considered when considering offloading interventions. Only unshod conditions were investigated, which may considerably alter pressure distribution, material compression and overall offloading effectiveness.

The PTI or the shear stress was not investigated. It was decided to focus this current study and examine three joints of interest (1st, 3rd and 5th MTPJs), due to the influence of a study where it was determined there is possibly no significance in reporting both PTI and peak pressures (30).

Conclusion

Traditionally, in the clinical setting it is hypothesised that the thicker the offloading material the better the effect. Indeed, this is the case however, one must consider the shifting of force to other areas of vulnerability on the plantar aspect of the foot. Results from this study should allow a better insight into the mechanical redistribution associated with the use of plantar padding in offloading, and the possible implications associated with this redistribution, especially if the patient wears unsuitable footwear. This is integral if the aim of the clinician is to reduce plantar stresses in a ‘high risk’ compromised foot.

Abbreviations

Kilopascal	kPa
Plantar metatarsal pad	PMP
Metarsophalangeal Joint	MTPJ
Body Mass Index	BMI
Foot Posture Index	FPI
Semi-compressed felt	SCF
Peak plantar pressures	PPPs
Pressure time integral	PTI

Declarations

Ethics approval and consent to participate

Ethics was fully obtained on the 5th June 2018 from the College of Medicine, Nursing and Health Sciences (CMNHS) Research Ethics Committee within NUI Galway.

Consent for publication

N/A

Availability of data and material

All data generated or analysed during this study are included in this published article (and its supplementary information files).

Competing interests

The authors declare that they have no competing interests.

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N/A

Authors' contributions

LC and CM conceptualised the project and developed the topic idea. LC conducted data collection, data extraction, data analysis. CM participated in data analyses and interpretation. Both authors drafted, critically reviewed, and approved the final manuscript.

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Figures

Figure 1

Bony Landmarks

Figure 2

Plantar Pressure Data Trend Plot