Reliability of Shore Hardness as a Surrogate for Heel Pad Stiffness: A Correlative Study Using Ultrasound Imaging

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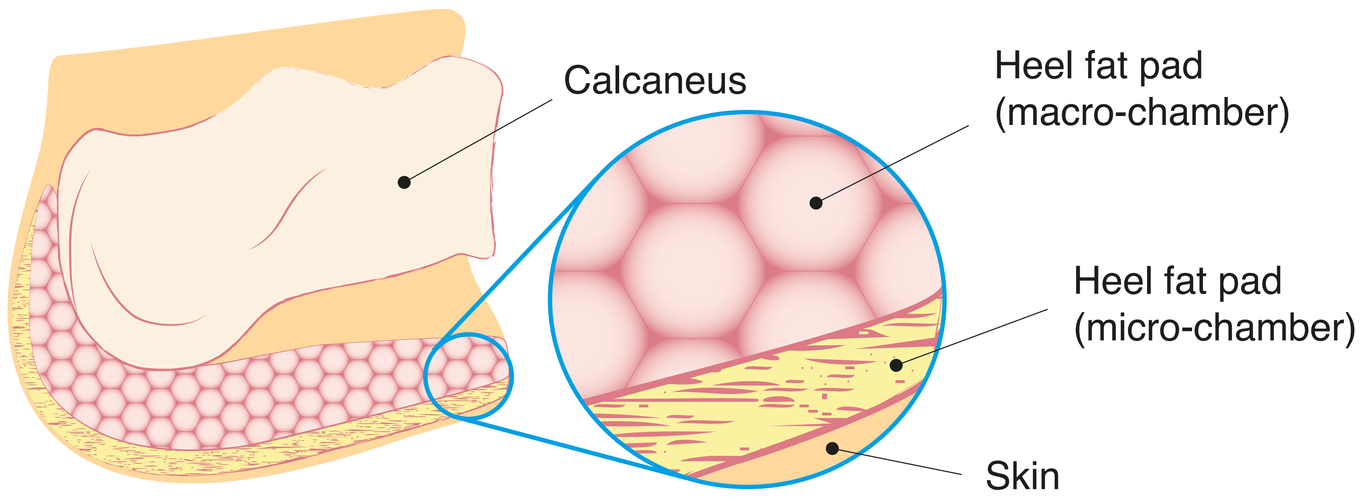

Figure 1. Cross-sectional schematic of the heel pad, showing the calcaneus, overlying skin, micro-chamber and macro-chamber fat pads; inset (right) zooms in on the layered architecture of skin, micro- and macro-chambers.

INTRODUCTION

Shore hardness (SH) is widely used as a quick, non-invasive index of plantar-tissue stiffness, but its ability to reflect in vivo heel-pad mechanics – especially deeper layers – remains a question under investigation [1, 2].

METHODS

Unloaded SH measurements were compared with ultrasound-derived tissue compressibility (Elasticity Index, EI) under half- and full-body weight in healthy adults based in UK, India and Namibia.

SH was recorded on participants' right heels using an AD-100 durometer (Figure 2a). Ultrasound images of skin, micro-chamber and macro-chamber layers were acquired at near-zero, half body weight (BW) and full BW using a portable L15 HD3 probe (Figure 2b-d). For each layer, EI was calculated as the thickness compression (%) relative to near-zero load. Pearson correlation coefficients (*r*) between SH and EI were determined for (a) skin alone, (b) skin and micro-chamber layers, and (c) all layers.

RESULTS

Table 1 presents *r* and *p*-values between SH and EI for different tissue layer combinations: (1) skin only, (2) skin and microchamber combined, and (3) all three layers combined.

The findings indicate weak, non-significant statistical correlations between SH and EI across the three layer combinations. This suggests that SH is not an effective surrogate for the stiffness of the heel pad layers under half and full BW.

Figure 3a-f depicts the histograms of EI for the three layer combinations under the two loading conditions, notably revealing positive (compression) and negative (expansion) of the heel pad.

CONCLUSION

SH does not reliably reflect the compressive properties of the heel pad layers under half- and full-body weights.

REFERENCES

[1] PE Chatzistergos et al. (2022). Med. Eng. Phys., 105: 1-7.
[2] PE Chatzistergos et al. (2024). Sensors, 24: 1-11.

Table 1. Pearson's correlation (with p-value) between heel Shore hardness (SH) and the elasticity index (EI) of different tissue layers for a population (N=186) of barefoot and shod participants based in UK, India and Namibia.

Layer(s)		Skin	Skin & Micro−chamber	Skin, Micro− & Macro−chamber
Half−body Weight	Pearson's *r*	−0.021	−0.012	0.034
	p−value	>0.75	>0.85	>0.60
Full−body Weight	Pearson's *r*	−0.032	−0.091	0.068
	p−value	>0.65	>0.20	>0.35

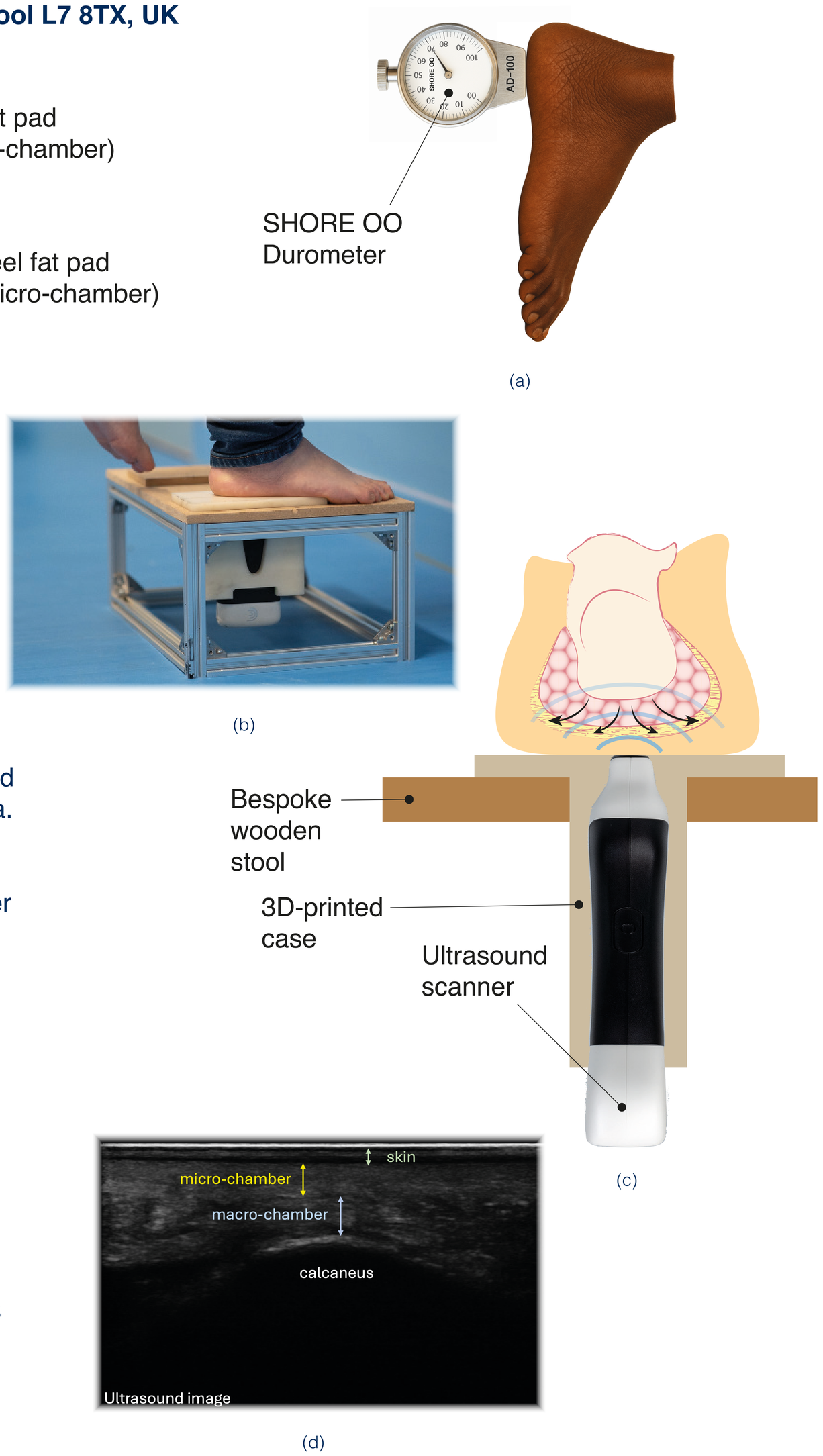

Figure 2. Experimental setup: (a) Shore OO durometer used to measure the hardness of the heel pad, (b) heel loaded on a bespoke wooden stool with integrated ultrasound probe, (c) schematic of the ultrasound scanner positioned beneath the heel, and (d) ultrasound image of the heel pad under load showing skin, micro- and macro-chambers, and calcaneus.

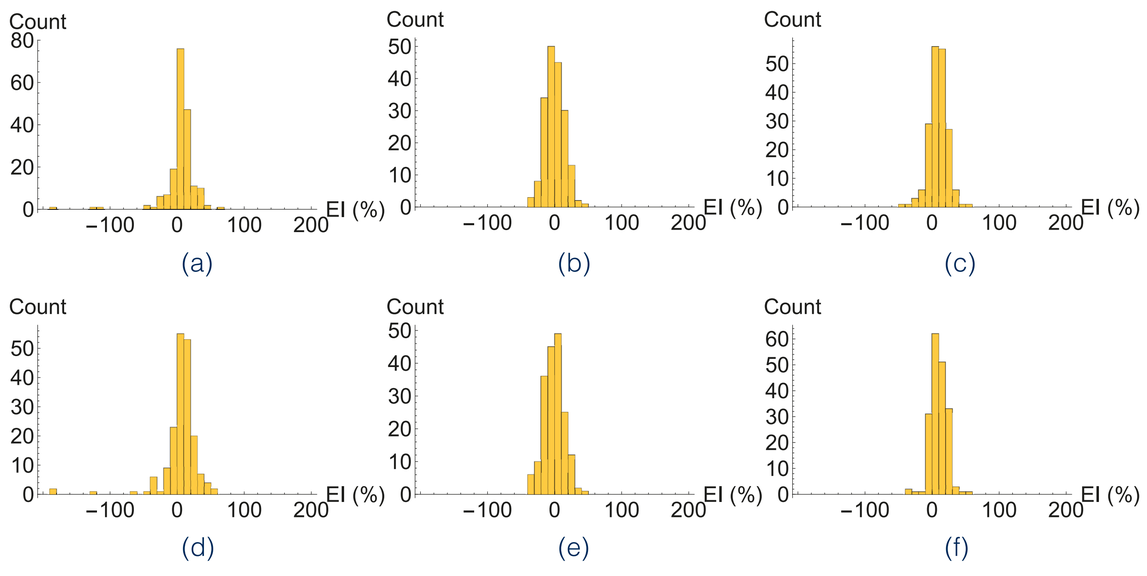

Figure 3. Histograms of EI (%) under half BW (a–c) and full BW (d–f) for (a,d) skin only, (b,e) skin and microchamber combined, and (c,f) all three layers combined.