Clinical performance diagnosing alleged exposure to falanga

A phantom study

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Abstract

Background: Falanga torture involves repetitive blunt trauma to the soles of the feet and typically leaves few detectable changes. Reduced elasticity in the heel pads has been reported as characteristic sequelae and palpatory testing of heel pad elasticity is therefore part of medicolegal assessment of alleged torture victims.

Objective: The goal was to test the accuracy of two experienced investigators in determining whether a heel pad model was soft, medium or hard. The skin-to-bone distance in the models varied within the human range.

Method: Two blinded investigators independently palpated nine different heel pad models with three different elasticities combined with three different skin-to-bone distances in five consecutive trials and categorized the models as soft, medium or hard.

Results: Two experienced investigators were able to identify three known elasticities correctly in approximately two thirds of the cases. The skin-to-bone distance affected the accuracy.

Conclusion: The use of clinical examination in documenting alleged exposure to torture warrants a high diagnostic accuracy of the applied tests. The study implies that palpatory testing of the human heel pad may not meet this demand. It is therefore recommended that a device able to perform an accurate measurement of the viscoelastic properties of the heel pad be developed.

Keywords: torture, falanga, heel pad, palpation, clinical examination

Introduction

The human heel pad is a complex structure consisting of a fat pad with micro- and macro-chambers divided by an intricate fibroelastic septation. The fat pad is contained by the internal heel cup, a ligament that encircles the fat pad as a functional link.

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between the septal structure and the subcutaneous tissue. The structure of the septation is designed to avoid any outflow of fat from single compartments and hence they are resistive to compressive loads.1,2

The heel pad presents non-linear viscoelastic characteristics, as the majority of soft body tissues. The term viscous implies that it deforms as a function of time under a given load, and the elastic term that once the deforming load is removed, the tissue returns to its original configuration. Viscoelastic materials have the ability to absorb energy and thus to reduce the magnitude of impact forces by extending the time course of the impact event. In the heel pad, the viscous and elastic features correspond to the fat cells and septa, respectively. Trauma to the heel pad may result in destruction of the complex structure with resulting permanent impairment of its function as a shock absorber.3,4

Falanga torture involves repeated applications of blunt trauma to the soles of the feet including the heel pads. One of the characteristic permanent changes reported at clinical examination is the flattened shape of the loaded heel, which is believed to be caused by a destruction of the intricate septation with resulting medial and lateral displacement of the fatty tissue of the heel pad.5-7 At palpation, the calcaneus is more easily felt under the skin, so the heel pad feels too soft. Palpatory testing of heel pad elasticity has therefore become part of medicolegal assessment8 of alleged torture warranting a high diagnostic accuracy of the test.

The validity and reliability of palpatory testing of heel pad elasticity is, however, not known. In assessing the accuracy of a diagnostic test it is necessary to compare test results with a reference standard (gold standard) or a confirmed diagnosis. Comparing test results to self-reporting of prior exposure to falanga clearly represents a methodological problem since it is the alleged exposure to falanga that is to be validated by the test.

Hence, the goal of this study was to test the accuracy of two experienced investigators in determining the elastic properties of a heel pad model with known elasticity by palpation. Three different heel pad models were developed – a soft, a medium, and a hard. As a confounding factor the skin to bone distance in the model was varied within the human range.

Material and methods
The mould: The heel pads used in this study were created by embedding part of an artificial calcaneus in an elastic material by use of a mould (Figure 1). To mimic the tuberosity of the calcaneus bone, a plastic calcaneus (AMS Superbones, Washington, USA) facing upwards was placed on a pedestal that was in turn attached to the bottom plate. By varying the height of the pedestal, different skin-to-bone distances were made.

PV A cryogel: The heel pad was modelled by use of a particular viscous liquid composed of 10% of polyvinyl alcohol (PVA) dissolved in water-based material. It provides an excellent model of the human tissue since the elastic modulus of PVA cryogel is controllable by varying the number of freeze/thaw cycles or the PVA concentration. Bought as a liquid, PVA cryogel changes into a gel by a freeze/thaw process.

Skin-to-bone distance: From eleven papers describing unloaded heel pad thickness, we calculated the mean (M) skin-to-bone distance to 17 mm with a standard deviation (SD) of 3 mm (Table 1). In the present study, we used three skin-to-bone distances: M - SD, M, and M + SD, i.e. 14 mm, 17 mm, and 20 mm, respectively.
Selection of elasticity: Twelve cryogel cubes (three of each) were made with one through four freeze/thaw cycles – each cycle making the sample harder. The elasticity of the samples was measured by compression testing applying an Instron test machine with a 250 N load cell. Elastic moduli of foot pad tissue in the range from 24 kPa to 306 kPa have been reported.9-11 The PVA samples match this range well.

Two experienced physicians selected the cubes made with two, three, and four
freeze/thaw cycles as representative of the human range of heel pad elasticity, i.e. soft, medium, and hard. The three different elasticities combined with three different skin-to-bone distances gave nine different heel pad models.

Palpation tests: Two investigators (KA and BDS) palpated the models in five consecutive trials each. Each trial consisted of palpating the model n times. In each trial we wanted the probability of guessing a model correctly all n times to be less than 0.05. Since, the chance of guessing correctly is 1/3 at each palpation, n became three (1/3^3 < 0.05). A trial therefore consisted of 27 palpations of the nine models in a random order (as each model had to be palpated three times).

A wide area of the examination table was covered and the investigator could not see how many models existed. The investigators were told that each model contained a calcaneus and that the models were soft, medium, or hard. They were not informed that the skin-to-bone distance varied. The investigator was allowed to familiarize herself with one model to get to know the shape. She was not told whether it was soft, medium, or hard. She was then blindfolded and given the models in a predefined computer-generated random order. There was no time limit. The investigator had to categorize each model as soft, medium or hard. There was a 30 minutes break between trials.

After three trials, the investigator was shown the nine models and was explained about the different skin-to-bone distances. She was allowed to familiarize herself with the nine models. She then performed two more trials blindfolded.

Statistics
We tested the independent accuracies of the two investigators in the 5 trials based on the proportion of correct answers (%), with an emphasis on the elasticities applied, enabling estimation of the difference between these. The null-hypothesis was two-fold: that there were no differences between (i) trials or (ii) elasticities. We applied the Cochran Q-test for homogeneity,12 and evaluated the amount of heterogeneity on the basis of I^2.13 These differences between trials and elasticities were combined based on an empirical Bayes methodology, applying the method of moments estimator proposed by DerSimonian and Laird14 using Review Manager (RevMan version 4.2 for Windows, Copenhagen, Denmark). We used the total dataset for each investigator (135 binomially distributed yes/no test samples per assessor) to estimate the overall accuracy for each investigator. We calculated the 95% confidence intervals (CI) based on 10,000 bootstrap samples – allowing us to estimate the median (proportion of correct answers), and the corresponding 2.5th and 97.5th percentile of the bootstrapped empirical data distribution.15

If there was no difference between the two investigators over the 5 trials, or over the three elasticities the pooled results (270 observations) would be used for an analysis of the interaction between skin-to-bone distance and elasticity applying a standard χ^2-test (with 4 degrees of freedom; elasticity × skin-to-bone interaction). Except for the homogeneity and empirical Bayes analysis, the SAS® statistical package (SAS 9.1.3 executing on the XP PRO platform; Copyright [c] 2002-2003 by SAS Institute Inc., Cary, NC, USA) was used for the statistical analyses.

Results
Performance by trial: The two investigators performed almost identically with approximately 2/3 correct answers (Figure 2), with the following proportions correct for KA and BDS: 67% (bootstrap 95% CI: 56 to
78%) and 66% (54 to 77%), respectively. As presented in Figure 2, there was no difference between the percentage correct answers between assessors across trials (p=0.91; $I^2=0\%$); the combined difference between percent correct answers was +1 %-point (95% CI: -10 to +12 %-point). The performance did not improve when the investigators knew about the varying skin-to-bone distance and had become familiar with the nine models (trial 4 and 5).

**Performance by elasticity:** The two investigators had a very similar performance with the lowest accuracy in the soft models, slightly higher accuracy in medium models and highest accuracy in hard models (Figure 3). There was no difference between the percentage correct answers between assessors across elasticity ($P=0.25; I^2=28.8\%$); the combined difference between proportions was -1 %-point (95% CI: -13 to +10 %-point).

**Performance by skin-to-bone distance:** There was a significant elasticity $\times$ skin-to-bone interaction ($p=0.0003$), suggesting that a clinical assessor’s ability to answer correctly varies across elasticity as the skin-to-bone distance changes (Figure 4). A superficial bone position (14 mm) made it easier to correctly identify a hard model; whereas, a deep bone position (20 mm) made it more difficult to identify a hard model correctly. Exactly opposite findings were made in soft models. In medium models, the intermediate bone position gave highest accuracy.

**Discussion**

The study showed that two experienced investigators had almost identical performance in determining whether a heel pad model
**Figure 3.** Performance of the two investigators by elasticity.
Left: The bars show the percentage of correct answers for both investigators by elasticities soft to hard (with 95% CI).
Right: The differences between elasticities were combined based on an empirical Bayes methodology and the amount of heterogeneity was evaluated on the basis of $I^2$. The data consistently show that the investigators perform better with increasing hardness and that they agree.

**Figure 4.** Combined performance over elasticities and skin-to-bone distances.
Left: The absolute number of correct answers for each elasticity is presented by skin-to-bone distance. Because of the agreement (Figures 2 and 3), the results were pooled in order to evaluate this interaction.
Right: The three graphs present the three elasticities plotted against the skin-to-bone distance. Each elasticity has its own pattern as skin-to-bone distance varies. E.g. a superficial bone makes the model feel harder and vice versa for a deep bone. The horizontal line marked median is the overall percent correct answers (with empirical 95% CI) across assessors, based on the bootstrapped median and the 2.5th and 97.5th percentiles.
was hard, medium, or soft. Their accuracy of two thirds is double that of chance and is not impressive considering the medicolegal use of heel pad palpation in the evaluation of alleged falanga torture victims.

By using a heel pad model with a known and controllable elasticity, we had the unique opportunity to accurately test the human ability to classify into soft, medium, and hard by means of palpation. We made it easy for the investigators by creating a very primitive model with only one type of “tissue” in comparison to the complex structure of the human heel pad with skin, subcutaneous connective tissue, and the complex structure of the heel pad itself with septation and spiral structure of chambers with fat. Our very limited number of classes (soft, medium, hard) further made it easy for the investigators in comparison to the continuous variation in the human heel pad elasticity. We therefore expect that our investigators will have a lower accuracy in a human material and the observed accuracy of two thirds should be seen in this context.

The variation in skin-to-bone distance made the models slightly more realistic although the variation again was discontinuous with only three classes exemplifying the human mean +/- SD. When the bone was close to the skin, the model felt harder resulting in 100% accuracy for the hard model with smallest skin-to-bone distance. Likewise, when the bone was deep, the model felt softer leading to 100% accuracy for the soft model with highest skin-to-bone distance. It was interesting that the investigators did not improve their performance when this variation was known and they had familiarized themselves with the models. We postulate that this will also be the case when the human heel pad is palpated: we know there is a variation in the skin-to-bone distance, which will affect our impression of hard versus soft just as the elasticity itself, but we do not know the individual skin-to-bone distance.

We believe there is a need for a device capable of measuring the elastic properties of the heel pad in order to obtain more credible evidence in the evaluation of alleged falanga torture victims. Theoretically, the device could record force and displacement when pressed against the heel pad. A series of corresponding force and displacement recordings during compression and decompression will allow us to measure the elastic properties of the heel pad. However, this device will need to take into account the variation in skin-to-bone distance. This is because the elastic nature of any tissue will change dramatically toward hard when a certain degree of compression has been reached. Therefore, we need to find an algorithm for the influence of skin-to-bone distance upon force-displacement data in order to allow for comparison between subjects with different skin-to-bone distances. This distance could be obtained with ultrasound.

Conclusion

The use of clinical examination in documenting alleged exposure to torture warrants a high diagnostic accuracy of the applied tests. Our study implies that palpatory testing of the human heel pad may not meet this demand.

Two investigators experienced in evaluation of heel pads in torture victims had an accuracy of approximately two thirds when palpatting and classifying simple cryogel heel pad models as being soft, medium, or hard. The variation in skin-to-bone distance in the models highly influenced the results. We recommend that a device able to perform an accurate measurement of the visco-elastic properties of the heel pad be developed. Such a device needs to take the individual skin-to-bone distance into account.
Roles: STP was chief investigator and guarantor, responsible for literature search, study design, data collection, data analysis, drafting, revision, and final approval. SM was responsible for literature search, model development, elasticity measurements, study design, data collection, data analysis, drafting, revision, and final approval. JW was responsible for model development, elasticity measurements, study design, data collection, data analysis, drafting, revision, and final approval. KA was responsible for data collection, revision, and final approval. BDS was responsible for data collection, revision, and final approval. JIB was responsible for elasticity measurements, revision, and final approval. RC was responsible for study design, data analysis, drafting, revision, and final approval.

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