MECHANICAL PROPERTIES OF THE HUMAN HEEL PAD: A COMPARISON BETWEEN POPULATIONS

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INTRODUCTION

The initial point of impact during many footfalls is the heel pad, its role is to help absorb and dissipate the impact forces [1]. It is composed primarily of collagen reinforced chambers filled with densely packed fat cells [2]. The mechanical properties measured in vivo suggest the heel pad has low stiffness at loading of one body weight, and exhibits large energy losses [3].

There is evidence that human heel pad mechanical properties change with age [3], and certain disease or clinical abnormality (e.g. diabetes [4]). The reasons for these changes in mechanical properties are not clear, and one potential reason is due to changes in weight bearing activity levels. The purpose of this study was to compare the mechanical properties of the heel pad between runners, who repetitively load the heel pad during training, and cyclists, who during training do not load their heel pad.

METHODS

Ten competitive long distance runners (height: 1.66 m ± 0.06, mass 56.3 kg ± 5.7), and 10 competitive cyclists (height: 1.77 m ± 0.08, mass 71.1 kg ± 12.1) volunteered for this study. All subjects had no previous or current plantar foot injury, and the cyclists had no running history (determined to be more than 2 days a week of running). The subjects provided informed consent, with all procedures approved by the Institutional Review Board.

Thickness of the unloaded heel pad was measured using real-time B-mode ultrasonography (Aloka SSD-625, Conneticut, USA) with a 7.5 MHz linear array scanhead. Measurements were taken after the subject had not placed weight on their heel pad for 10 minutes. The ultrasound images were digitized (Scion Image for Windows) and the mean of five measurements used to compute heel pad thickness.

A heel pad indentation device, adapted from the one described in Rome and Webb [5], was used to measure the mechanical properties of the heel pads. Heel pad deformation and applied force were measured via the indentation device, for 5 trials per subject. The displacement and force data were low pass filtered with a second order Butterworth digital filter (cutoff = 4 Hz). Numerical integration was used to compute the ratio of the area within the hysteresis loop and the area under the loading curve; this indicated the energy loss between loading and unloading. A model was fitted to the force-deformation data [6], and then used to estimate heel pad stiffness at the same relative loading for each subject (5 % of body weight).

To evaluate the differences between the runners and cyclists heel pad properties a repeat measures analysis of variance (ANOVA) was used ($p < 0.05$).

RESULTS AND DISCUSSION

Heel pad thickness was statistically significantly greater for the cyclists (14.9 mm ± 1.5) compared with the runners (13.6 mm ± 1.2), but if this thickness was expressed relative to subject height then there was no significant difference (cyclists: 0.75 % ± 0.07; runners: 0.82 % ± 0.08).

There was no significant difference between the groups in percentage energy loss during loading and unloading (runners: 61.4 % ± 8.6; cyclists: 62.5 % ± 4.6). Model fits to the data produced R^2 values in excess of 0.96. Heel pad stiffness for the runners was significantly less than that of the cyclists (runners: 17.1 $N.mm^{-1}$ ± 3.0; cyclists: 20.4 $N.mm^{-1}$ ± 4.0).

CONCLUSIONS

The two populations showed no differences in heel pad thickness or energy loss due to hysteresis, but did have different pad stiffnesses. This difference in heel pad stiffness would influence the forces experienced by the body during gait containing a heel strike [7]. The indentation device used for measuring the mechanical properties only applied low loads to the heel pad, but has the advantage that measurements can be made *in vivo*, and that compared with other methods for making these measurements *in vivo* soft tissue motion does not contaminate the results [8]. These results indicate that the nature of the activity undertaken by subjects influences their heel pad properties. This finding may be important, for example, when considering differences in heel pad properties between the young and elderly [e.g., 3].

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