REGIONAL MECHANICAL PROPERTIES OF THE PLANTAR APONEUROSIS

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INTRODUCTION

The plantar aponeurosis (PA), or plantar fascia, is a major contributor in the support of the arch of the foot during weight bearing. Approximately one million people per year are affected by PA disorders (e.g., rupture or plantar fasciitis) [1]. PA anatomy and function has been extensively studied utilizing cadaveric tissue testing [2,3] and computational models [4,5]. However, the regional cross sectional areas and mechanical properties of the PA are largely unknown. In this study, we characterized the cross sectional area and mechanical properties of the PA at four local regions (medial, middle proximal, middle distal and lateral). This information is crucial in understanding etiology of PA disorders and developing treatments for them.

METHODS

Fifteen PA specimens were harvested from fresh-frozen cadaveric feet (age: 70.0 ± 6.7 yr, body weight: 773 ± 178 N). For each foot, soft tissues surrounding the PA were removed. Bone-PA-bone specimens were isolated from the foot by performing osteotomies at the calcaneus, metatarsal necks and the bases of the proximal phalanges (Figure 1). Cross sectional areas (Figure 1) of four regions were quantified using molding, casting and sectioning techniques [6]. For mechanical testing, five specimens were randomly assigned for each test region (middle proximal and middle distal regions were tested from the same specimen). The distal regions that were unrelated to the test were resected. The calcaneus and distal bones were potted in polymethylmethacrylate. Mechanical tests were performed using an ElectroForce 3400 material testing machine equipped with an environmental chamber (temperature 30°C, near 100% humidity). Five frequencies (0.5, 1, 2, 5, 10 Hz; 30 cycles displacement control triangle waves) were used in a randomized order. A target peak load was calculated from 96% body weight [2] and scaled by the area ratio of the distal regions.

Deformation of the region of interest was achieved by the use of a high-speed camera recording at 100-1000 frames per second. The frames were post-processed to remove lens distortion; then 2D in-plane deformations were analyzed in MATLAB. Peak stress, peak strain, modulus and energy loss were calculated for each frequency and region tested.

RESULTS AND DISCUSSION

The average cross sectional areas for medial (37.6 ± 11.0 mm\(^2\)), middle proximal (50.5 ± 11.9), middle distal (46.8 ± 15.6 mm\(^2\)) and lateral (14.4 ± 4.7 mm\(^2\)) regions were obtained. Stress-strain responses were non-linear with higher moduli at higher strains (Figure 2). Peak stresses, peak strains, moduli and energy losses varied across regions (two-way ANOVA; p < 0.0001 for all four variables), but were not significantly affected by frequencies except for the energy loss (p < 0.0001). Mean regional peak strains ranged from 5.1% (lateral) to 2.3% (middle distal) while mean regional peak stresses ranged from 8.58 MPa (lateral) to 5.67 MPa (medial). The highest and lowest averaged moduli were found at the middle distal (522.9 MPa) and the medial (239.0 MPa) regions, respectively. Overall observations suggest that the PA tensile responses are elastic (energy loss 3.5% to 8.6%) and frequency independent. This work also suggests that the material behavior of the PA differs by region.

![Figure 1](https://example.com/figure1.png)

**Figure 1:** Left: Isolated PA specimen (potted calcaneus), M = medial, L = lateral, D = distal, P = proximal; Right: (a) PA casting, (b) distal and (c) proximal cross sectional areas.

![Figure 2](https://example.com/figure2.png)

**Figure 2:** Stress-strain responses from 1 Hz tests (n=15).

REFERENCES


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