Investigating PMHS Plantar Thickness and Stiffness at Various Sites Using Ultrasound

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Introduction

In lower extremity biomechanics research, ultrasound imaging is used to quantify characteristics such as thickness and stiffness of the plantar soft tissue of the foot. Quantifying differences in thickness and stiffness is important for studies characterizing the lower extremity soft tissue of PMHS to ensure appropriate experimental design and accuracy. Quantifying this variation could also allow for comparison to living populations. However, little has been done to determine the degree of variation across feet as well as between regions of the plantar surface in PMHS. The goal of this study is to investigate differences in plantar soft tissue thickness and stiffness within and between PMHS feet.

Methodology

Twenty-eight male and female PMHS (age 76±12 years; weight 59±15.3 kg; height 167±9.9 cm) were ethically obtained through The Ohio State University’s Body Donor Program for ultrasound measurements. A custom-built ultrasound fixture equipped with a Lumify ultrasound probe, a load cell, and hand crank were used to apply controlled incremental force to the plantar soft tissue and acquire static displacement images for measurement. The ultrasound probe was used to identify landmarks, and the load cell was used to view real-time measurements of force application. Each PMHS foot was positioned in the fixture to acquire images of each bilateral regions of interest (ROI) including the calcaneus, metatarsal 1, and metatarsal 5, at applied forces of 0, 5, 10, 15, 20, and 30 Newtons.

At each region of interest, distances between bone and the outermost layer of skin at each applied force were measured using ImageJ. A force-displacement curve was plotted for each ROI. A linear trendline was applied to each curve, the slope of which represented the stiffness of the ROI. The stiffness and baseline thickness of each ROI was compared to those of the other two ROIs within a foot (ANOVAs) and between right and left feet (paired t-tests).

Results and Conclusions

Current results indicate calcaneal thickness and stiffness varied between left and right feet (p<0.05), while neither metatarsal thickness nor metatarsal stiffness varied across feet (p>0.05). Variations in calcaneal thickness and stiffness between feet could be a result of foot dominance. Metatarsal 1 and 5 plantar soft tissue thicknesses were similar within the same foot, but plantar soft tissue thickness varied significantly between the calcaneal and metatarsal regions. The difference in thickness between calcaneus and metatarsal surfaces within the same foot could potentially be caused by disease or variations in loading across the foot throughout the subject’s lifetime. All stiffness values were similar at different regions within the same foot. This new knowledge of variations in soft tissue characteristics in PMHS lower extremities should be accounted for and can be utilized to improve accuracy of results from future PMHS lower body testing.