

Correlation of Mechanical Tissue Properties and Signal Intensity via Magnetic Resonance Imaging

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I. INTRODUCTION

Blunt impacts to the thorax are common in motor vehicle crashes, in high-velocity non-penetrating impacts, and in contact sports [1]. To study these blunt impacts, computational models are being built. Ovine models are being created due to the large amount of experimental data available for high-velocity, non-penetrating impacts [2-3]. When modelling these situations, it is important for the tissues to be biofidelic. One of the first tissues impacted is adipose, making it a tissue of interest.

Adipose tissue is made up primarily of fluids, with 60–80% lipids and 5–30% water by mass [4]. The triglycerides in the tissue alone have a viscosity of 36.8 mPas, which is comparable to vegetable oil [4]. With the high proportion of fluids in the tissue, it is imperative that the fluid and the fluid movement are properly accounted for in material models. Accordingly, spherical indentation stress-relaxation tests were carried out on ovine adipose tissue, with results that varied widely between animal subjects. While there have been lots of studies to characterise the mechanical properties, there have been no studies to correlate them to medical imaging signal intensity [5-6]. Therefore, the objective of this study was to determine if there were imaging differences between animal samples, not just material differences.

II. METHODS

Magnetic Resonance Imaging (MRI)

Adipose tissue samples had been obtained post-mortem from another study, following all protocols set forth by the Wake Forest University Health Sciences Animal Care and Use Committee (#A22-103). A total of four tissue samples were obtained bilaterally from two different animal subjects. After procurement, samples were wrapped in saline-soaked gauze and frozen until experimentation. Specimens were thawed prior to imaging.

The MRI modality was chosen to be used to investigate the differences between tissues due to the potential for subsequent applications of living specimens and analysis of retrospective data. Specimens were imaged on a Siemens 3T Skyra scanner with 32 channel spine and 18 channel body coils (Siemens, Munich, Germany). Specimens were scanned using a 2-point Dixon method, with TR = 6 ms, TEs = 2.46 and 3.69 ms, in-plane voxel = 0.67x0.67 mm, slice thickness of 1 mm, and 5 averages, resulting in an image with fat and water in phase, and another image with fat and water out of phase. A fat-only image (0.5*(in phase – out of phase)) was used for analysis.

Image Analysis and Correlation

The fat images from the MRI scans were used for analysis. Image sets were loaded into Mimics (Materialise NV, Leuven, Belgium) and thresholded by intensity (Fig. 1). The volume of each thresholded range was then calculated for comparisons between samples.

Due to the large variation in previous mechanical testing, regions of interest (ROI) at test sites were then identified and an average intensity was calculated for each indentation in a ROI per mechanical test. While beyond the scope of this work, mechanical testing had been completed on these samples previously using spherical indentation and resulted in the instantaneous and relaxed shear moduli. An ellipse with the long axis approximately equivalent to the contact radius (6.3 mm) and the entire length of the short axis approximately equivalent to the testing depth (4 mm) from testing was used, with slight variation between image sets (area = 46.1 mm²). The average fat image intensity within the ellipse ROI was then calculated and normalised using the area of the ellipse ROI. A t-test was used to determine if a difference between the two animals ($\alpha = 0.05$) could be detected. A linear regression model was then fit to determine if there was a correlation between the shear relaxed modulus and the fat image intensity, as well as the shear instantaneous modulus and the fat image intensity.

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III. INITIAL FINDINGS

The preliminary results show a difference in fat image intensity between each animal with the general shape of the spread of data. As seen in Fig. 1, Animal 1's fat image intensity is more heavily right skewed than Animal 2. A sagittal image of the adipose tissue is shown in Fig. 2, along with a 3D rendering of the adipose tissue.

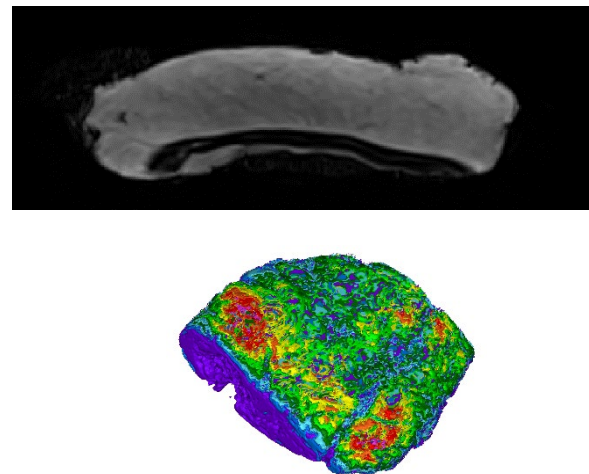
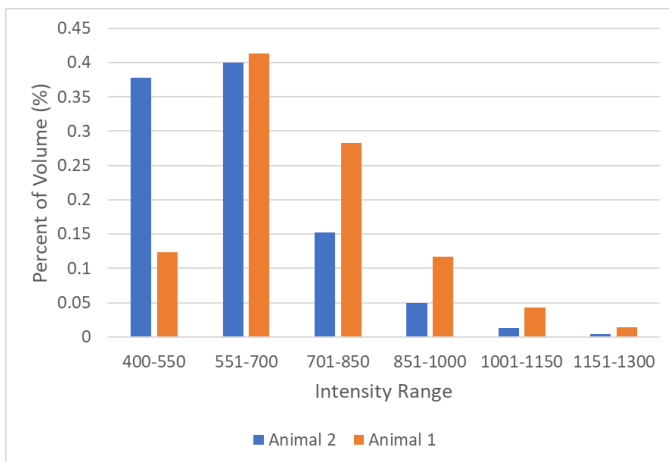


Fig. 1. Histogram of fat image intensity ranges by animal donor.

Fig. 2. Upper: MRI Dixon fat image of adipose. Lower: 3D rendering of adipose sample.

The fat image intensity is statistically different between each animal based on a t-test run on the preliminary data ($p < 0.01$). As for the preliminary modulus and intensity correlations, there is a clear difference in animal (Fig. 3), however the R^2 value with a combined subject linear regression is low for the instantaneous modulus ($R^2 = 0.01$). However, there appears to be a trend of decreasing shear modulus as a function of intensity.

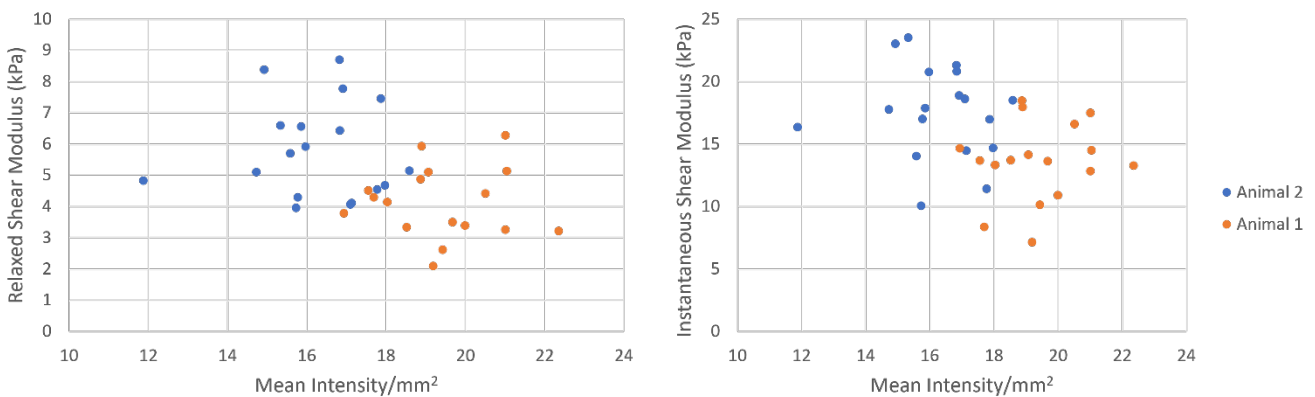


Fig. 3. Preliminary correlations between each shear modulus and normalised intensity.

IV. DISCUSSION

The objective of this study was to determine if inter-subject differences were noted between the intensity of MRI-based image data and the shear modulus between the samples of ovine adipose tissue. The first part of the objective has been met, where it is clearly shown that there is a difference between the two donor tissues. As for the second part of the objective, this study shows a decreasing trend between the intensity and local shear modulus, but the differences were not significant. Additional data may indicate a significant trend.

V. REFERENCES

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