Development of an FEA-based Ovine Adipose Model for use in High-rate Non-Penetrating Blunt Impact (NPBI) Studies

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Introduction

Ovine animal models are commonly used for trauma research, particularly within the field of high-rate non-penetrating blunt impacts [1-3]. Ovine animal models are particularly useful in evaluating lung injuries subsequent to thoracic blunt trauma due to their similar physiology and size to human lungs [2]. Due to the high costs of experimentation and increased volume of data that can be extracted from them, ovine finite element models are being developed to develop FEA-based injury risk criteria in high-rate loading environments. In these high-rate loading environments, the tissues that experience the highest internal energy rises during loading are the adipose tissue, hide, ribs, and intercostal muscle. Due to the lack of ovine material characterization in the literature, the goal of this study is two-fold: 1. To characterize the material response of ovine adipose tissue, and 2. To calculate short-term and long-term shear moduli for use in modeling a high-rate environment.

Methods

Refuse ovine adipose samples were obtained immediately post-mortem from an unrelated study (WFU IACUC #A22-103), following all protocols set forth by the Wake Forest University IACUC. A sample was dissected from each flank of the animals (N=2), for a total of four blocks of adipose tissue.

Non-destructive spherical indentation stress-relaxation tests were then run on each sample at a range of loading velocities: 0.2, 2, 20, and 200 mm/s (Figure 1). Once the indenter reached the target depth of 4 mm, the displacement was held for 90 seconds, and force, displacement, and time data were collected.

Prior to analysis, inertial loading was accounted for with each experiment, regardless of the loading velocity. The data was then analyzed in MATLAB (Mathworks, Natick, MA) and fit to a 3-parameter viscoelastic model (Equation 1) [4]. From this model, instantaneous and relaxed shear moduli were calculated.

\[ G(t) = C_0 + \sum C_k \exp\left(-\frac{t}{\tau_k}\right) \quad \text{Equation 1} \]

Each modulus will then be compared across loading rates and animal using a 2-way ANOVA (a=0.05).

Results and Discussion

Relaxed Shear Modulus (Figure 2):
- Animal donor significant (p < 0.001)
- No rate dependency (p > 0.05)

Results and Discussion (continued)

Instantaneous Shear Modulus (Figure 3):
- Human skin shear modulus ~4 kPa [5]
- High inter-sample variability
- Material model will be input into FEA model to study high-rate NPBI

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References