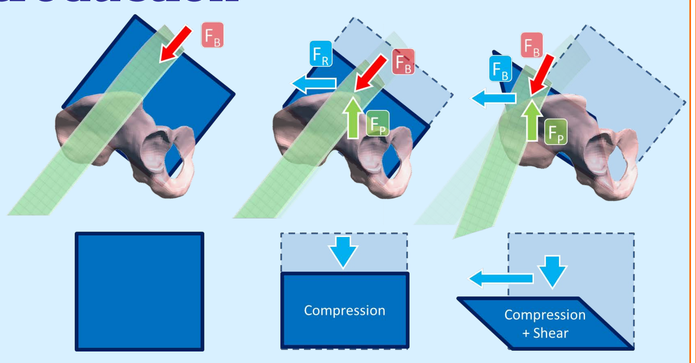
Material characterization of subcutaneous adipose tissue – a pilot study

Zhaonan Sun, Neil Singh, Bronislaw Gepner, Jason Kerrigan

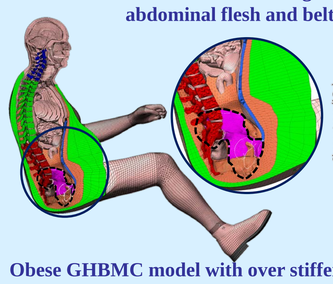
University of Virginia Center for Applied Biomechanics, Charlottesville, VA

Introduction

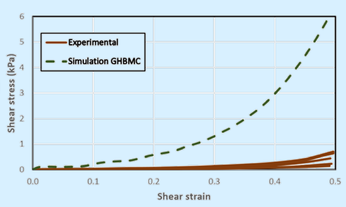
- Obesity is associated with increased fatality risk of occupant injuries relative to lower BMI occupants in automotive collisions
- Increased depth of abdominal soft tissue, results in delayed and limited engagement of the lap belt with the pelvis and increases the risk of pelvis submarining under lap belt, exposing obese occupant's abdomen to belt loading
- Pelvis submarining could not be replicated using existing obese human body models, partially due to over stiffened shear response of flesh material model



Mechanism of submarining : compression and shearing of the abdominal flesh and belt sliding over the iliac crest



Obese GHBMC model with over stiffened material cannot replicate submarining



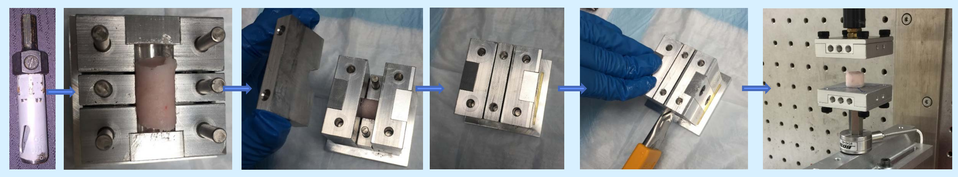
Material response of GHBMC abdominal flesh in shear

Objectives

- Develop a methodology to characterize the mechanical responses of abdominal adipose tissue in compression and shear at high loading rates that represent automotive crash conditions
- Collect data for determining the constitutive relationship of porcine subcutaneous adipose tissue

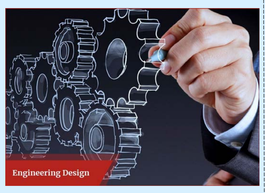
Methods

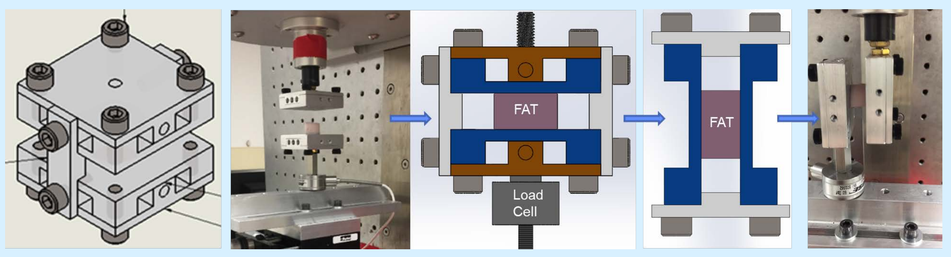
Sample preparation



- Design and fabricate a set of tools to cut soft tissue with consistent shape and dimensions

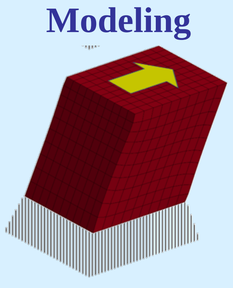
Testing Fixture Design

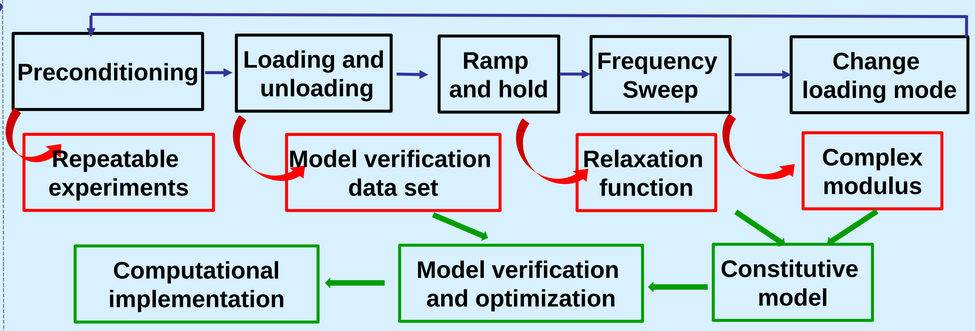




- Design testing tools that allow compression and shear on the same specimen

Data Acquisition, Analysis and Modeling

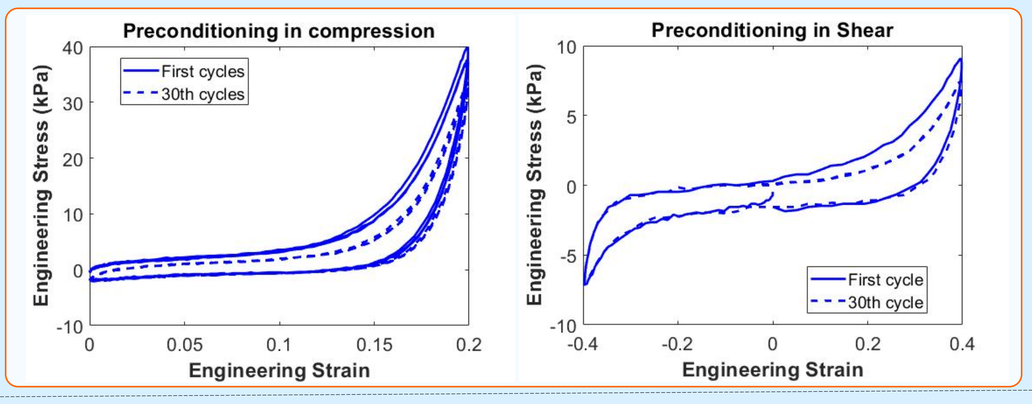




Results

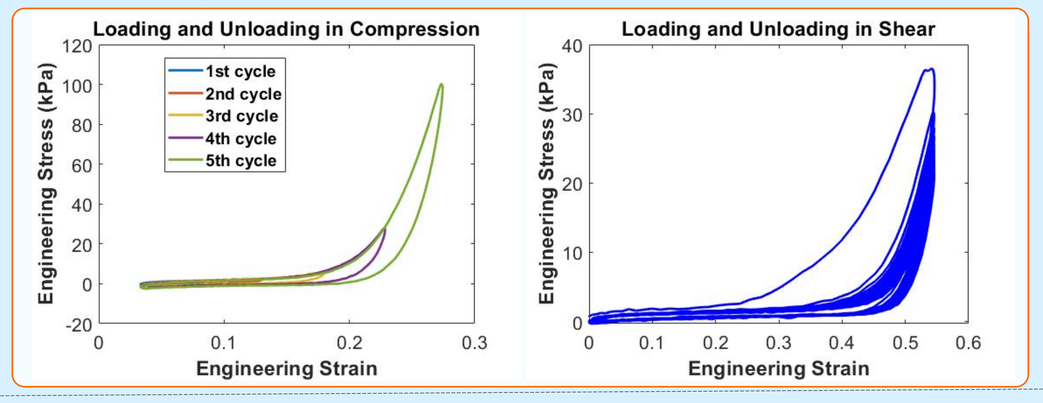
Preconditioning

- Consistent response was observed after preconditioning
- Mechanism for preconditioning remained unclear for adipose tissue



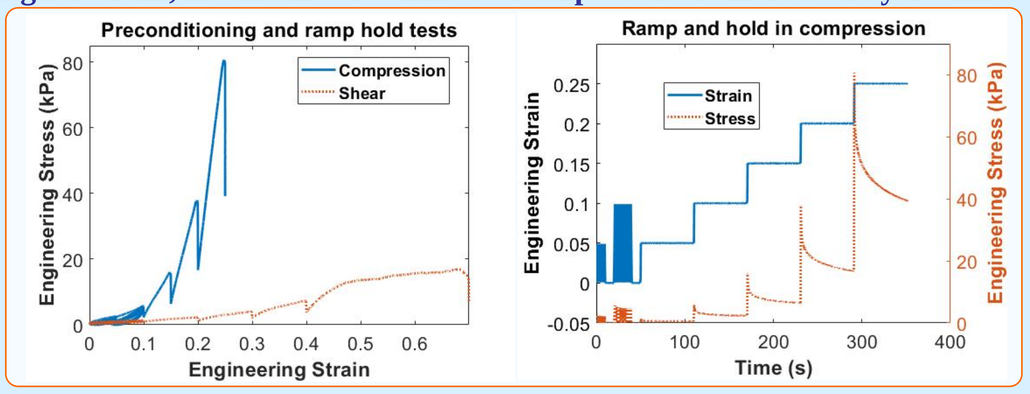
Loading and unloading

- Loading curves at the same strain rate followed the same path
- In shear, preconditioning effect was observed again



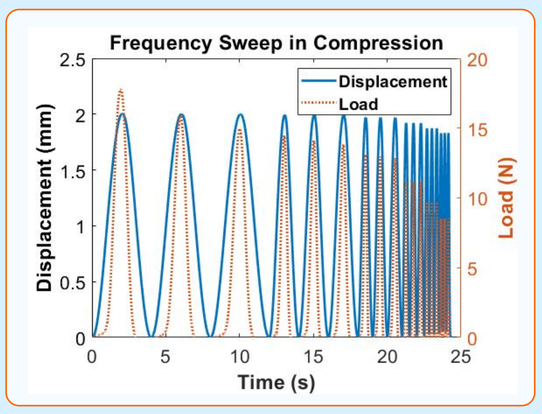
Ramp and Hold

- Consistent response was observed after preconditioning
- At higher strain, instantaneous stiffness of adipose tissue increased by 10 times



Frequency Sweep

- Frequency sweep tests were successfully performed up to 3Hz at 20% strain in compression
- Minor phase shift was observed
- Permanent deformation was observed after the test. On average, height of the specimen decreased by 20%
- Steady state was not achieved in the first three cycles



Discussion and Conclusions

- The results suggested viscoelastic behavior of the subcutaneous adipose tissue and different stiffness in compression and shear loading modes at automotive crash loading rates.
- This study demonstrated a methodology for future investigation of human subcutaneous adipose tissue properties with the application of improved subcutaneous adipose tissue modeling on existing human body models to replicate submarining kinematics.
- This effort will eventually enhance the human body models prediction of submarining injury risk and their application to designing optimized restraint systems.
- Human subcutaneous adipose tissue testing will be performed using adapted procedure from the current study

Acknowledgements

The authors would like to thank UVA's Office of Undergraduate Research for providing funding for the study

References:

[1] Mock et al., Accident Analysis & Prevention, 2002, 34(2), 221-228.
[2] Zhu et al., American journal of public health, 2006, 96(4), 734-739.
[3] Viano et al., Traffic injury prevention, 2008, 9(1), 59-64.
[4] Jehle et al., The American journal of emergency medicine, 2012, 30(1), 191-195.
[5] Reed et al., Traffic injury prevention, 2012, 13(4), 364-372.

CENTER *for* APPLIED BIOMECHANICS

Zhaonan Sun, zs2re@virginia.edu
4040 Lewis and Clark Drive, Charlottesville, VA 22911, USA