Experimental Characterization of Biological Tissue Mechanics

Nick Evans and Bethany Luke

Valparaiso University Department of Mechanical Engineering and Bioengineering

Abstract

The function of ligaments and tendons is to transmit tensile forces, allowing healthy, bodily motion. However, if improper loading is placed on the tissue, the structures may rupture leading to pain, loss of function, and reduced quality of life. To prevent rupture, loads must remain below the ultimate strength of the tissue, but the maximum stress that the tissue can withstand varies due to several factors such as age, sex, body temperature, loading history, hydration state, and strain rate. These factors can be tested in order to understand how they affect the tissue failure risk. Therefore, the objective of our research is to design and develop a lab procedure for future students to complete that experimentally characterizes the biological tissue mechanics. Load carrying tissues can be characterized by their stress-strain behavior utilizing a tensile tester. Using the tensile tester, the lab will consist of several experimental tests: freeze thaw cycles, varying strain rates, stress relaxation, and varying hydration. Creating a lab procedure for these experiments will allow students to describe both the viscoelastic properties of the tissue and the influences of strain rate on ultimate stress and ultimate strain. By measuring these quantities, we can gain a better understanding on the factors that affect tissue failure risk allowing for better treatment methods for injured athletes.

Objectives and Background

Stress Equation

$$\sigma = \frac{F}{A}$$

Stress – force per unit area when external forces are applied to the material

σ = stress
F = force
A = cross sectional area of specimen

Strain Equation

$$\varepsilon = \frac{\delta}{L_0}$$

Strain – deformation of a material based on stress

ε = strain
δ = current displacement
L_0 = initial length

- Ultimate Strength – maximum stress that the material can withstand while being stretched before breaking
- Viscoelastic – combination of elastic and viscous behavior where the stress applied to the material results in both an instantaneous elastic strain and a viscous (sticky), time-dependent strain
- Elastic Modulus – how resistive the material is to being deformed elastically when stress is applied

Materials

- Chicken
- Gloves
- Dissection Kit
- Ruler
- Personal Computer
- Instron 3343 Tensile Test Stand

Methods

- Extract tendons from chicken legs
- Wrap tendons in a wetted towel and store in a refrigerator
- Create test protocols for Instron software based on experiments we are replicating
  - Freeze-thaw cycles [1]
  - Varying strain rate [2]
  - Varying hydration [3]
  - Stress relaxation [4]
- Generate stress-strain curves for the four experiments using the refrigerated chicken tendons and tensile tester

Results

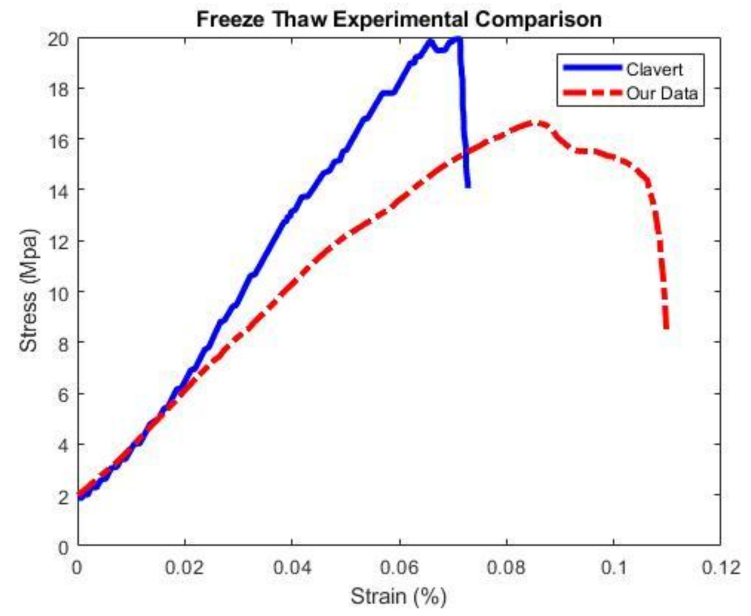

Figure 1: Comparing our experimental chicken tendon data to a human tendon [1]

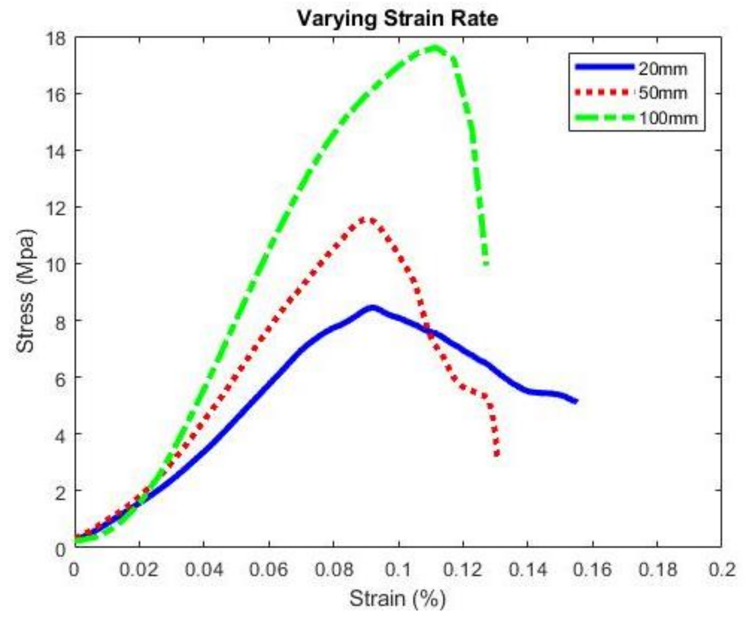

Figure 2: Comparing the effects of strain rate on the mechanical behavior of tendons [2]

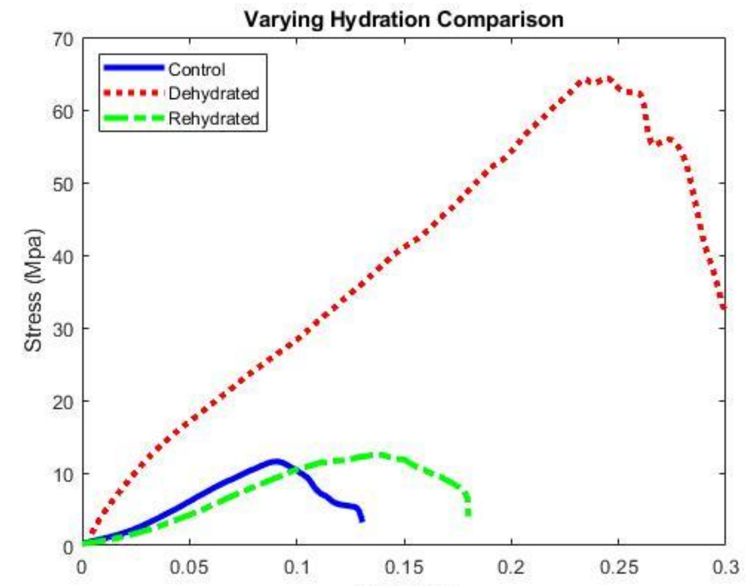

Figure 3: Comparing the effects of hydration to determine properties of tendons [3]

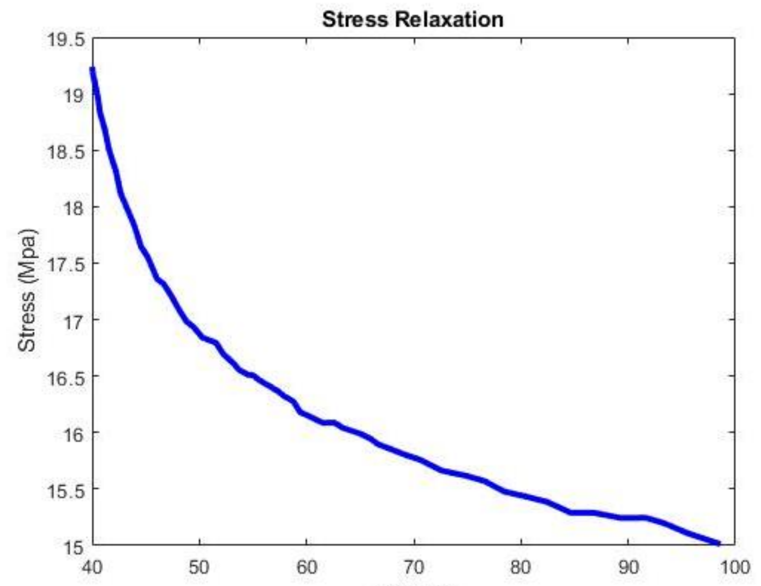

Figure 4: Effects of an applied strain rate and relaxation period on tendon [4]

Conclusions

- All four experiments were able to replicate the work based on other researchers' experiments
- Three of the four experiments were chosen to be completed by future students
  - Varying strain rate [2]
  - Varying hydration [3]
  - Stress relaxation [4]

Future Work

- Write up the lab procedure for the class, Biotechnologies Lab
- Have another person complete the lab based on the written procedure
- Work on other labs if time allows
  - Biomarkers lab
  - Constructing a pulse sensor
  - EMG acquisition

References

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[3] Hoffman, A. H., Robichaud, D. R., Duquette, J. J., and Grigg, P., 2005, "Determining the Effect of Hydration upon the Properties of Ligaments Using Pseudo Gaussian Stress Stimuli," J. Biomech., 38(8), pp. 1636–1642.med. Mater., 3(1), pp. 112–115.

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Contact

Author: Nick Evans
Nick.Evans@valpo.edu

Advisor: Bethany Luke
Bethany.Luke@valpo.edu