BMMB Lab C4

Compression Testing of Elastic Spring vs ViscoElastic Hydrogel

Results Slide Template

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III. STUDY DESIGN

Table 1. Exp. 1 - Control Samples.
(1) Elastic spring.

Group	Sample
1	Spring

Table 2. Foam Samples
Saline Bath Conditions??

Group	Saline Concentration	Sample #'s ("nn")
~~2A~~	~~High (1.0 M)~~	~~01-03~~
~~2B~~	~~Normal (0.15 M)~~	~~04-07~~
2C	Low (0.015 M)	08-10

Sample Group Assignments:
- A TBD
- B TBD
- C TBD

(updated 2021.06.29)

Spring sample is cylindrical.

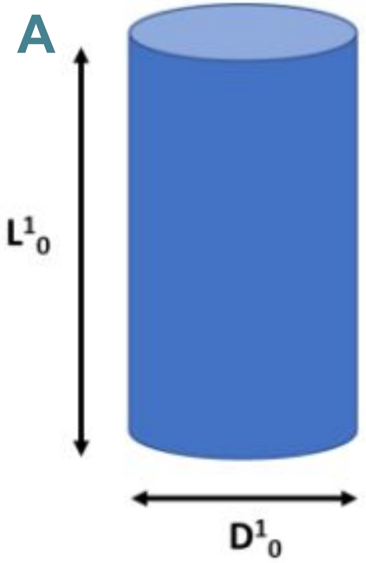
Table S1-1. Dimensions of sample 1, spring.

Variable	Description	Dimension [mm]
L_0	Initial Length	34.3
D_0	Initial Diameter	7.3

Table S1-2. Photos of sample 2, spring.

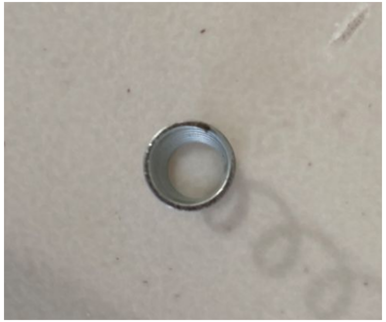
Image Filename	Sample View
Lab2_**1A_spring**_obl	oblique
Lab2_**1B_spring**_top	top
Lab2_**1C_spring**_side	side

A



B

C



D

Figure S1-1. Schematic, photos, and dimension measures of Sample 1, foam block. (A) Schematic of cylindrical sample. Photographs of sample from **(B) oblique**, **(C) top**, and **(D) side** views.

(updated 2021.04.22)

DISCUSSION

1. Confirming measurements two ways - importance of photographs, and their interpretation.

In both Biology and Engineering scientific studies, it is useful to show confirmatory measurements. The dimensions of a biological structure are important to determine in order to assess both structural and material properties.

A. How do your (1) caliper measurements and (2) photographs of apparent dimensions compare in terms of dimensions ? Be quantitative in your comparisons !

The spring measurement from the photo with ruler is not very accurate: the width looks close to 8mm (vs. 7.3 mm using the calipers) and the length looks close to 35mm vs. 34.3 mm using the calipers).

B. What factors affect each measure, and why might those make the measures different ?

The photographs are more inaccurate because of 1) precision of measurement using the ruler is less (increments of 0.1mm), 2) the angle of the photograph is taken, and 3) the distance between the spring and the ruler which causes distortion of 3D to 2D projection.

Test plan for sample 1, spring.
(A) Calculated sample heights (lengths). (B) Photo filenames.

1. Transfer length (height), L_0, of Sample 1 from Table S1-1.
2. From L_0, calculate 10% L_0 and the heights at targeted (10,20,30,40%) compression levels.
3. During test, take image at initial and each compression state, assigning filename that is pre-planned to identify *you*, *experiment*, *sample*, *image sequence*, and *content*; then, save to your experiment sub-folder.

Table S1-3. Compression test plans for Sample 1, spring.

Variable	Description	Dimension [mm]	Image Filename
L_0	Initial Length	10.0	FML_Lab2_**1D_spring**_00
ΔL	10% L_0 for compression	1.00	
L_1	Height at 10% compression = L - L_0	9.0	FML_Lab2_**1E_spring**_10
L_2	Height at 20% compression = L - $2L_0$	8.0	FML_Lab2_**1F_spring**_20
L_3	Height at 30% compression = L - $3L_0$	7.0	FML_Lab2_**1G_spring**_30
L_4	Height at 40% compression = L - $4L_0$	6.0	FML_Lab2_**1H_spring**_40

Test plan for sample 1, spring.
(A) Calculated sample heights (lengths). (B) Photo filenames.

Table S1-3. Compression test plans for Sample 1, spring.

Variable	Description	Dimension [mm]	Image Filename
L_0	Initial Length	34.3 mm	Lab2_**1D_spring**_00
ΔL	10% L_0 for compression	3.43 mm	
L_1	Height at 10% compression = L - L_0	30.87 mm	Lab2_**1E_spring**_10
L_2	Height at 20% compression = L - $2L_0$	27.44 mm	Lab2_**1F_spring**_20
L_3	Height at 30% compression = L - $3L_0$	24.01 mm	Lab2_**1G_spring**_30
L_4	Height at 40% compression = L - $4L_0$	20.58 mm	Lab2_**1H_spring**_40

Compression of spring with incremental loading: from 10% to 40%

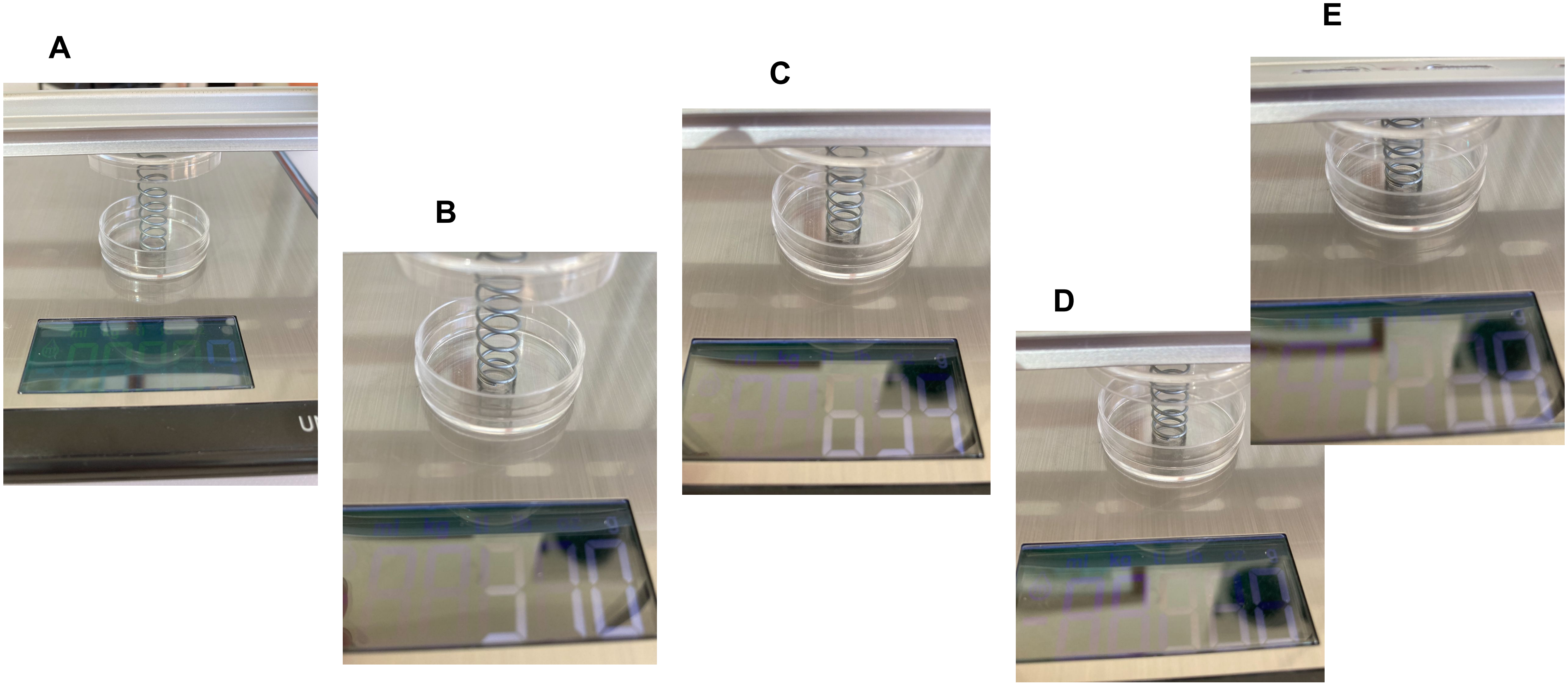


Figure S1-2. Photos of spring at various states of compression. (A) Reference state. **(B-E)** compressed to **(B)** 10%, **(C)** 20%, **(D)** 30%, **(E)** 40%.

(updated 2021.06.29)

DISCUSSION

1-2. Photographs illustrating Biomechanics.

Photographs to demonstrate deformation were helpful previously in understanding stretchy.

A. From your photographs, estimate the amount and percentage of compression at each state.

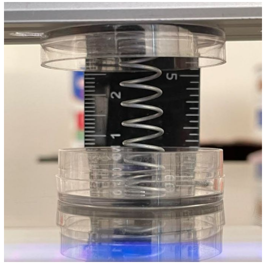
Height estimated from photos 20mm, 23mm, 27mm, 30mm, 34mm

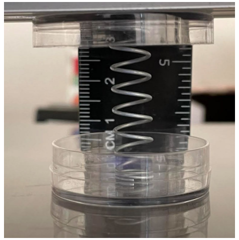
See table.

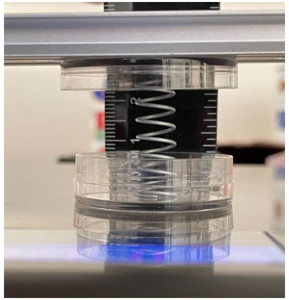
B. Do the estimates confirm the intended compression level ? Why or Why not ?

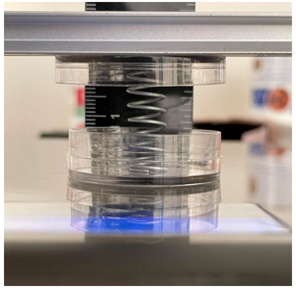
Yes, the measurements from the photos are pretty close to the intended compression. They are within the expected measurement error.

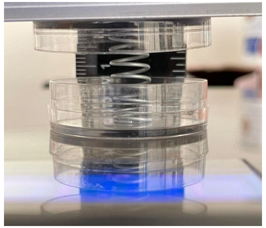
Photo Height (mm)	Compression (mm)	% compression
34	0	
30	4	12%
27	7	21%
23	11	32%
20	14	41%











(updated 2021.06.29)

S1 (spring) exhibited linear elastic behavior.

- Applied displacement was from 0-13.7 mm in increments of 3.5 mm.
- Over the test range, measured mass increased from 0 to 1288 g.
- Force vs displacement showed a positive linear (R^2=0.999) relationship, with
  - slope (stiffness) of 0.931 N / mm
  - intercept of -0.124 N.

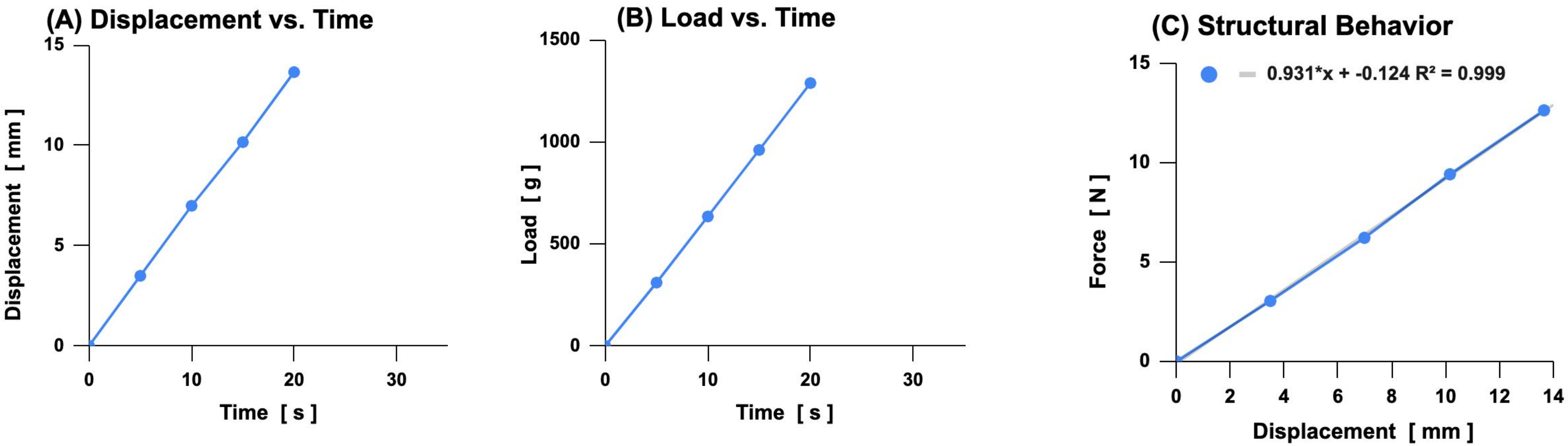


Figure S1-3. Structural compressive behavior of Sample 1, spring. Time course of **(A) Displacement** and **(B) Load. (C) Structural behavior** shown as **Force vs Displacement**, with linear fit.

DISCUSSION

1-3. Load-Displacement property of a spring.

Biological structures usually exhibit complex mechanical behavior. A “spring” is often modeled as ideally linear.

A. From your results, how ideal did your spring behave ?

Based on my results, my spring behave ideal because the graphs show a usual linear relationship.

B. What aspects of the experiment are important to help attain “ideal” behavior ?

Making the compressions at a constant rate of change. If the compressions were inconsistently large and small, the spring could be overly compressed and not return to its original state.

III. STUDY DESIGN

Table 2. FOAM Sample Saline Bath Conditions.

Group	Saline Concentration	Sample #'s ("nn")
~~2A~~	~~High (1.0 M)~~	~~01-03~~
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Sample Group Assignments:

A TBD
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C TBD

The gel was liquified so I had to use foam samples instead. The reaction time was very quick, so I shortened the measurement time.

(updated 2021.06.29) <Foam> sample is <uniform, cylindrical, square block>.

Table S1-1. Dimensions of sample 1, foam.

Variable	Description	Dimension [mm]
L_0	Initial Length	23.9 mm
D_0	Initial Diameter	24.7 mm

Table S1-2. Photos of sample 1, foam.

Image Filename	Sample View
Lab2_**1A_foam**_obl	oblique
Lab2_**1B_foam**_top	top
Lab2_**1C_foam**_side	side

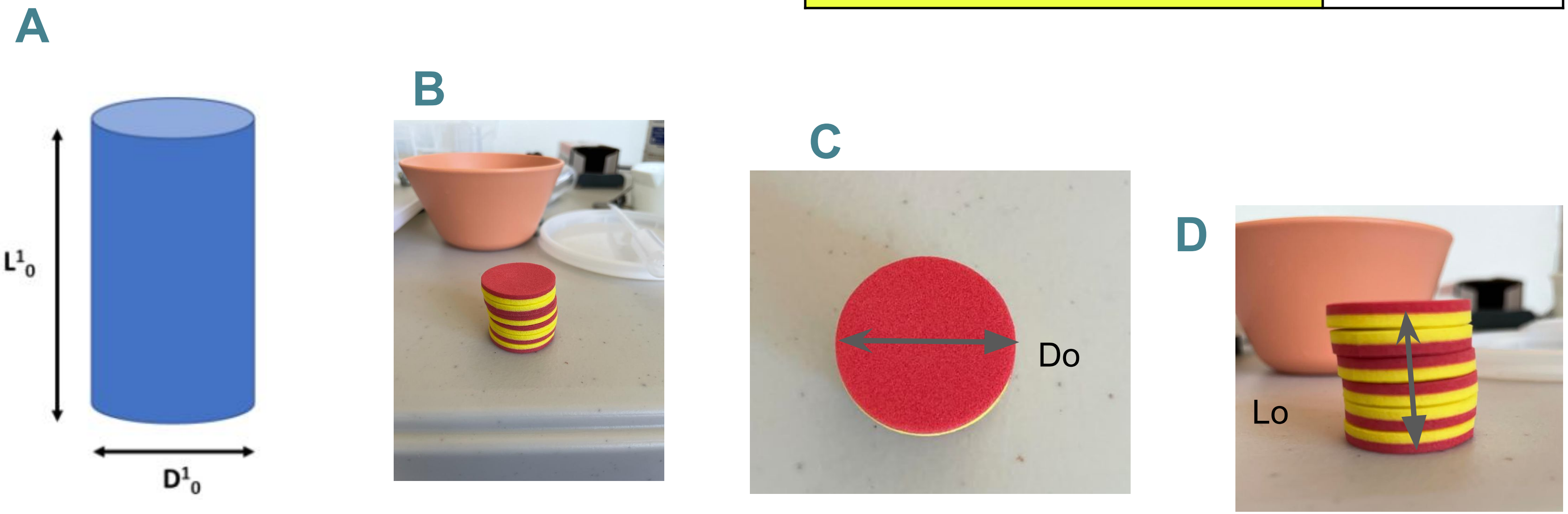


Figure S1-1. Schematic, photos, and dimension measures of Sample 1, spring. (A) Schematic of cylindrical sample. Photographs of sample from **(B) oblique**, **(C) top**, and **(D) side** views.

(updated 2021.04.22)

DISCUSSION

2-1. Confirming measurements two ways - importance of photographs, and their interpretation.

In both Biology and Engineering scientific studies, it is useful to show confirmatory measurements. The dimensions of a biological structure are important to determine in order to assess both structural and material properties.

A. How do your (1) caliper measurements and (2) photographs of apparent dimensions compare in terms of dimensions ? Be quantitative in your comparisons !

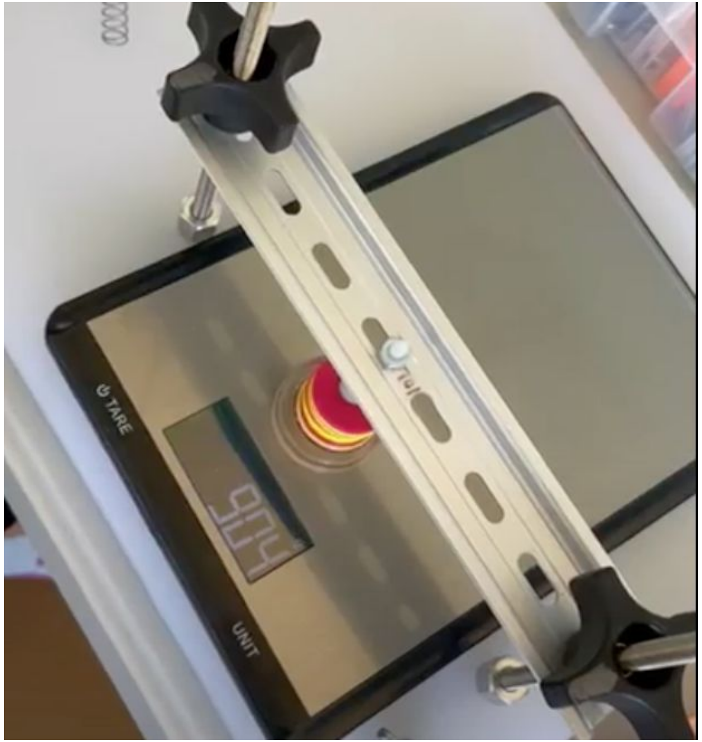
The spring measurement from the photo with ruler is not very accurate: the width looks close to 8mm (vs. 7.3 mm using the calipers) and the length looks close to 35mm vs. 34.3 mm using the calipers).

B. What factors affect each measure, and why might those make the measures different ?

The photographs are more inaccurate because of 1) precision of measurement using the ruler is less (increments of 0.1mm), 2) the angle of the photograph is taken, and 3) the distance between the spring and the ruler which causes distortion of 3D to 2D projection.

Figure Snn-2. Video of hydrogel during compression test. **(T=0)** Reference state. **(T1)** compressed to 15%, **(T1+240s)** 15% after 240s, **(T2)** compressed to 30%, **(T2+240s)** 30% after 240s.

Figure Snn-2. Video of hydrogel during compression test. (T=0) Reference state. **(T1)** compressed to 15%, **(T1+15s)** 15% after 240s, **(T2)** compressed to 30%, **(T2+240s)** 30% after 240s.



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https://drive.google.com/file/d/1_LT9kUu1MWz7s6AaEaadIs-sXkV0Yp6h/view?usp=sharing

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Foam in 1.5% conc. of saline exhibits stress-relaxation response.

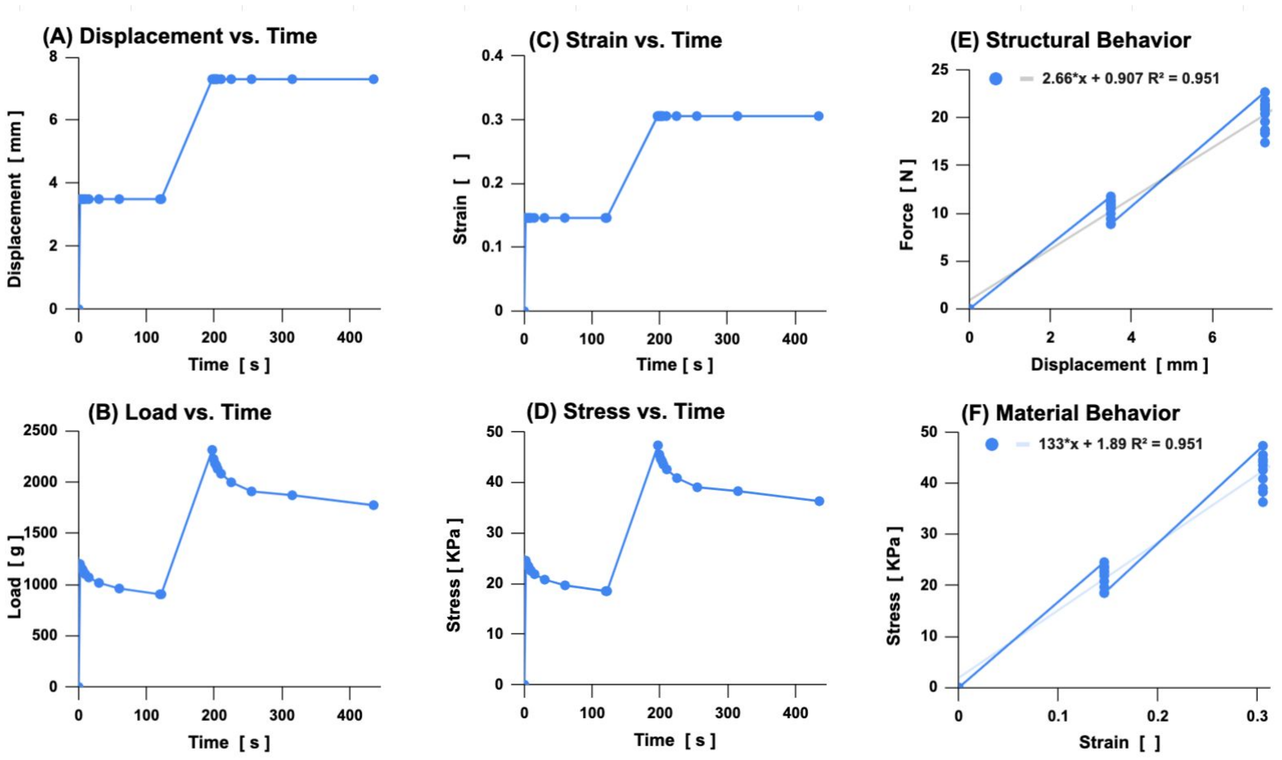

Figure Snn-3. Characterization of foam sample in 1.5% conc of saline as a (A,B,E) structure and (C,D,F) material. Time course of **(A)** applied displacement, **(B)** measured load, and calculated **(C)** strain and **(D)** stress. Behavior as **(E)** structure and (F) material, with linear fits. Compression taken as +.

RESULTS

2-2. Biological sample - handling, appearance, and geometry.

A. How easy or difficult was it to handle the specimen in the dry and wet states ? Did you find any maneuvers that were helpful or to avoid ?
It was easier to handle the specimen in the dry states because I would not have to worry about the liquid around it. I found it helpful to put the dry specimen in the petri dish before adding the solution.

B. From the time of procurement through the end of a biomechanical test, the biological specimen should maintain its state and not deteriorate. What might be advantages of providing the samples to you in a desiccated (dry) format ?
It could last longer, which could then be preserved and its shape would not change so easily.

C. Biological samples are subjected to a variety of fluid environments. In this lab, you are purposefully varying the NaCl concentration from what is approximately normal, to a very dilute, or to a very concentrated solution. How uniform did your sample appear ? Why do you think that may be ? Do you think it is related to the NaCl concentration ?
I only used on sample of concentrated solution because I was using a foam sample.

DISCUSSION

2-3. Appearance and behavior of sample during mechanical testing.

A. How easy or difficult was it to ***apply compression*** to your sample ? Did you find any maneuvers that were helpful or to avoid ?
It was tricky to place the sample in the middle of the petri dish because when I added the solution, it would move. But after that, I was able to apply compressions easily.

B. We planned for you to apply compression of ~15% and ~30%. From viewing your video, was the level of compression what you expected ? Give possible reasons for why the compression level may be off (low or high).
The compression level may have been too low because after I compressed the sample, it would keep decreasing until it reached a number that stayed on the scale for a while.

C. Tissues and materials are characterized in part by "Poisson's ratio". See the explanation in Wikipedia. Did the sample exhibit any change in lateral dimensions ? Why might this be ?
The sample did not exhibit any change in later dimensions. This might be because foam is harder to deform in shape when I have many pieces stacked together.

DISCUSSION

2-4. Biomechanical behavior of hydrogel sample.

A. From the time course plots, did your sample exhibit viscoelastic behavior during either or both bouts of compression ?
Only my foam sample exhibited viscoelastic behavior. The spring did not.

B. Normally, biological hydrogels, such as articular cartilage and intervertebral disc, undergo relatively little compression during normal loading, despite joint compressive stress being 5-10 MPa. Was the time course of your experimental result consistent with the extent to which a hydrogel reaches equilibrium during loading *in vivo* ? Why or why not ?
No, the time course was not consistent with the loading in vivo. The foam in my experiment took 2 minutes or longer to reach equilibrium, whereas biological hydrogels take much quicker.

C. Your previous fits of Y vx X, such as Force vs Displacement of a spring, or Load vs weight, data yielded some very linear results, while others did not. From panels (E) and (F), did your sample exhibit linear behavior (R^2=1, or slope the same along the entire set of data) ? Why do you think it did, or didn't ? What is the significance of the linearity, or lack thereof ?
It was not linear because once the load is applied, it takes time for the material to release the stress from the load. For the foam, the viscoelasticity behavior is caused by the foam releasing water.