BMMB Lab C1

Biomechanical Springs: Structural Properties

Results & Discussion Slide Template

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(updated 2021.04.13)

Scale is calibrated with objects of known weight in low & high ranges.

Figure 1. Calibration of scale by mass measurement of light and heavy objects with defined weights. (A) 1, 2, or 3 US quarters. **(B)** 3 canned food containers.

DISCUSSION

1. Range & Sensitivity of Instrument

Using an instrument within an appropriate working range is important for (A) obtaining precise and accurate results and (B) not damaging the instrument. Although the “load cell” that you are using is a “kitchen scale”, it has a sensitivity (lowest detectable value) and range that exceed the capabilities of many research grade instruments. Its range is 0 - 10 kg (kilogram) with readings of 1 g (gram).

A. In units of Newtons and also ounces, what is its sensitivity.

1g which is about 0.0098 N. Using conversion, 1g = 0.035 oz which is about 0.0105N

But the scale “measures” in 0.01 oz increments, which suggests that it could measure to 0.028N

B. In units of Newtons and also ounces, what is its upper limit ?

10 kg which is about 98N. Using conversion, 10kg is about 352.75 ounces..

C. How could you do a simple manual test to confirm that the range is 0-10 kg, and ***not*** the more standard range of only 0-5 kg ?

I placed my hand on the scale and pushed down. It went from 0-10.00 then it errored out.

(updated 2021.06.29)

Scale is <somewhat, slightly, highly> linear from 0-15 g & 0-5,000 g.

Table 1. Calibration of 10 kg scale.

Lab 01B	**Scale Calibration**				
Date	6/27/2022	Start Time	8:00		
Name	Natasha S	End Time	8:30		
Scale	329				
	Linearity Check				
Object Description	**Object Mass**	**Actual Mass**	**Measured Mass**		
	[g]	**[g]**	**[g]**		
resolution	**±1**				
Tare		0.00	0		
coin 1	5.00	5.00	5.0		
coin 2	5.00	10.00	10.0		
coin 3	5.00	15.00	17.0		
Can 1	411.00	426.00	471.0		
Can 2	411.00	837.00	942.0		
Can 3	411.00	1,248.00	1410.0		
Total Mass	1,248.00				

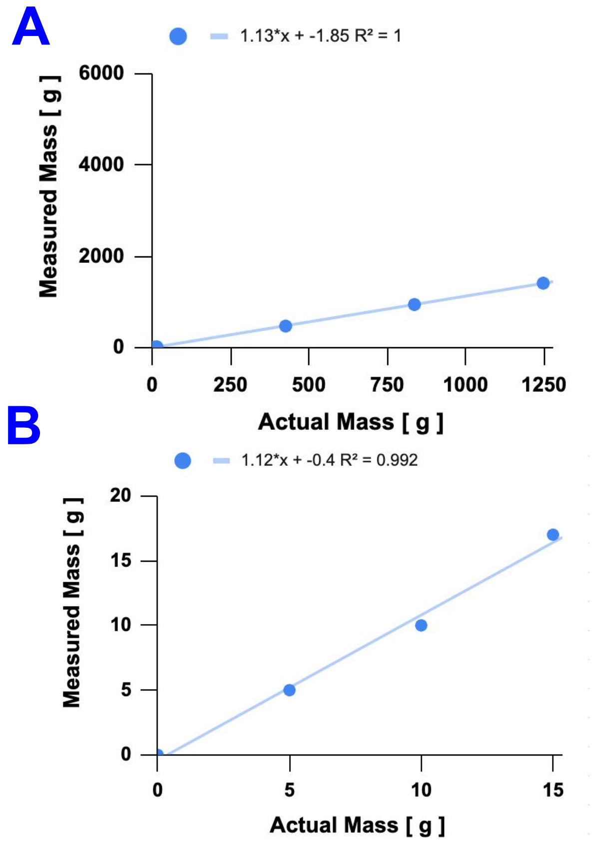

Figure 2. Scale calibration. (A) Full (high) range. **(B)** Low range.

(updated 2021.04.13)

DISCUSSION

2. Linear Calibration over Usage Range

Some scientific instruments provide a convenient linear range where the input (x) is related to the output (y) by the formula for a line, y=mx+b. Such instruments need to be periodically calibrated or checked for calibration using standards. This calibration should span the usage range. For your calibration, you used, as test inputs, three light objects (coins) and three heavy objects (cans of food, bottles of water, etc). After obtaining calibration lines, for a reading (y) of an unknown object, the equation is rearranged to be x=(y-b)/m, and used to determine x. For a calibrated scale, we simply take the reading and weight to be identical, eg, b=0, m=1, assuming an ideal calibration.

A. Find the “standard” value of your coin type, and provide the reference (link).

A standard quarter typically weighs 5.670 grams according to the US Mint.
(https://www.usmint.gov/learn/coin-and-medal-programs/coin-specifications)

B. How close (absolute values, and percentage values) were your weight measurements for your coins to their standard value ? Do you think your measurements are reasonable, and why or why not ?

These were pretty close to their standard values, but the scale is not accurate enough to detect the tenths and hundredths of a gram. Absolute Value difference was 0.670 grams. Percentage Value: 11.8%

C. What would be problematic with using (converting the readout, y, to a value, x) (1) the Full-range linear fit for small weights and (2) the Low-range linear fit for large weights ? Give explanations and numerical examples.

(Case 1) Small weights would not be accurate enough because it can only measure to one gram. In the case of a cartilage, which is very light, it won’t be very accurate.
(Case 2) A low range linear fit for large weights would not be accurate enough because the slope would not be very sensitive to small changes. That is why I had to measure both the coins and the food cans.

(updated 2021.04.13)

Stretchy was tested in various configurations.

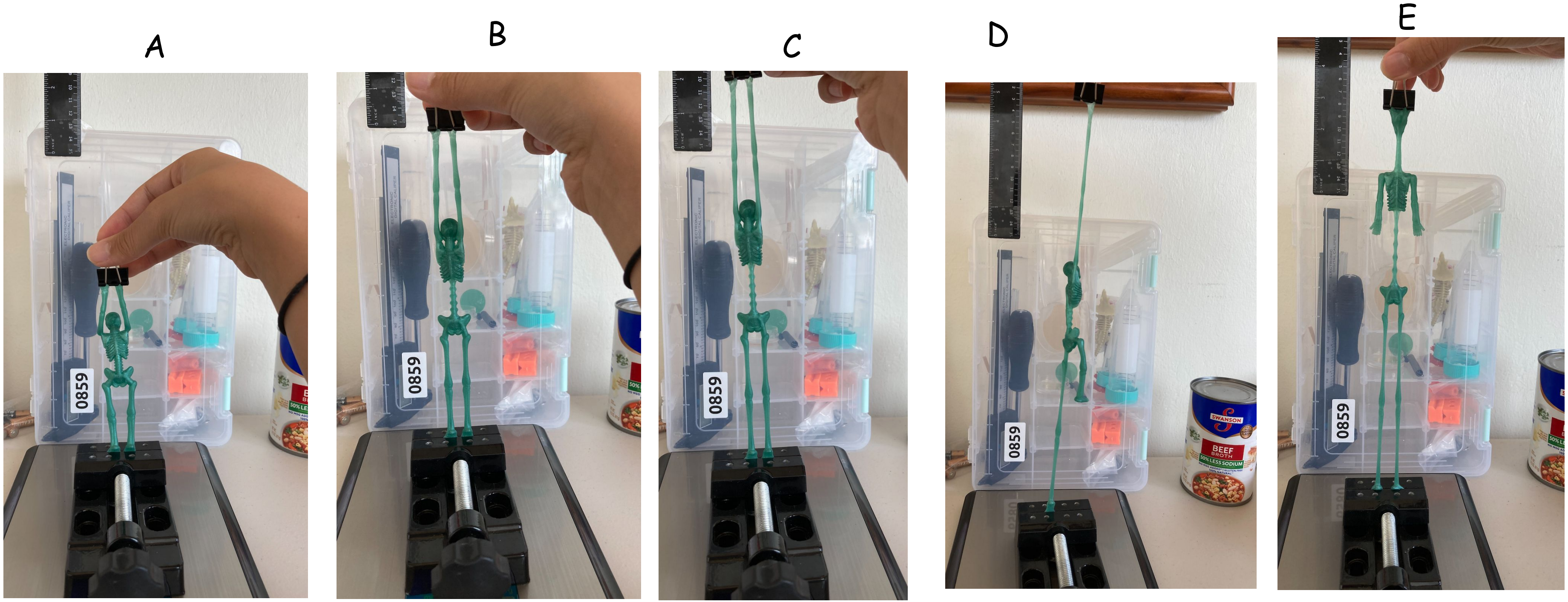

Figure 3a. Tensile testing of Stretchy in various clamp configuration. (A-C) 2 arm + 2 legs. **(A)** Resting. **(B)** Mid-range. **(C)** High-range. Alternate stretchy configurations: **(D)** 1 arm + 1 leg, **(E)** head stretch. Box & black rulers in background.

(updated 2021.04.13)

Stretchy was tested in various configurations. (Arms and legs only)

F G H I

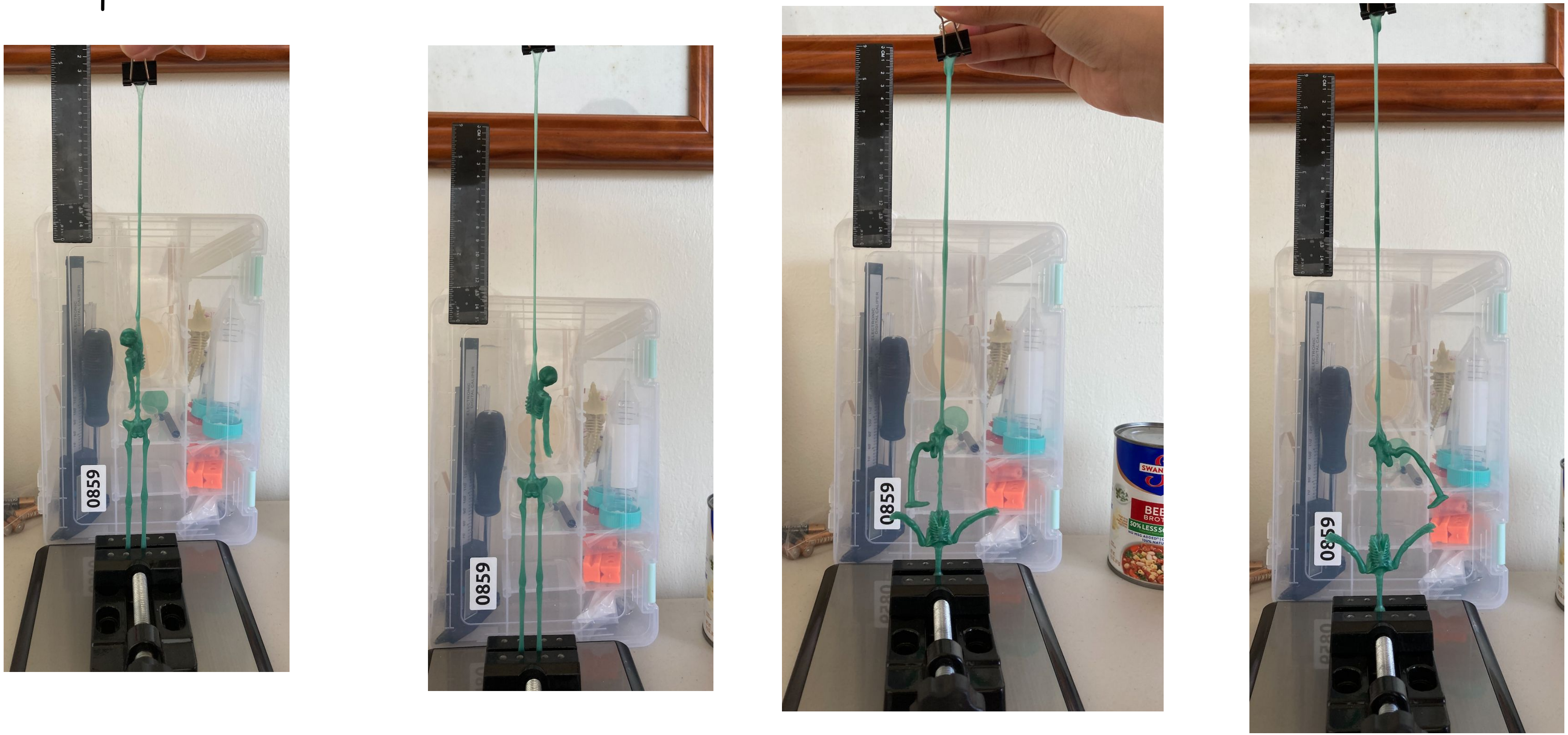

Figure 3b. Tensile testing of Stretchy in various clamp configuration. (F) right arm **(G)** left arm **(H)** Left leg **(I)** Right leg. Box & black rulers in background.

(updated 2021.04.13)

DISCUSSION

3. Practical Issues with Tensile Testing for BIOmechanics.

Tensile testing is complicated by end effects and sample gripping methods, even for traditional materials. Visualizing the test is important to interpret the results. Your test on Stretchy exemplifies many of the complexities for soft biological materials.

Cannot access Raising the Bar article~

A. See the (… wo major instrument suppliers. For gripping the sample for a tensile test, what were the gripping challenges and solution?

(1) reinforcement bar -

(2) Rat skin - Challenges: She had to make sure to not tighten the tensile grips too much to break the sample. Solution: She added another pin to make sure that the tensile grip is secured to the sample holder.

B. For gripping Stretchy, you used two types of clamps which are typical of fixtures used for biomechanical testing. The base clamp was a vise type grip, whereas the top clamp was a binder clip. What are relative (dis)advantages of the two in terms of positioning (1) location and (2) ease of application.

(1) Location - one disadvantage for the binder clip in terms of location is that it was always the clamp that was moving to different heights. This movement probably was not as accurate as it could have been because the binder clip might not have been exactly at 5 inches at resting point, 11 inches at half point, and 13 inches at full point. Also, the various ways that an individual can clip the binder to the stretchy could have minimized or maximized the length of the true stretchy. On the other hand, the base clamp stayed in one position the entire time.

(2) Ease - The base clamp is more eased of application because it stays put and prevents the whole structure from moving. It is also heavier, which makes the structure more stable.

DISCUSSION

3. Practical Issues with Tensile Testing for BIOmechanics. (cont'd)

C. For panels A-C, approximately how uniform is the stretch between the right (R) vs left (L) arms, and R vs L legs ? Provide some simple visual estimates of lengths to give a quantitative basis to your answer.

R vs L arms - The left arm was significantly more stretchy than the right arm. As shown in figures 3f and 3g, the left arm stretched about 4 inches more than the right arm.

R vs L legs- The left leg was significantly more stretchy than the right leg. As shown in figures 3h and 3i, the left leg stretched about 2.5 inches more than the right leg.

D. For panel B&C vs D and vs E, for the same overall stretch, how are the local stretches of specific body parts similar or different ?

B&C vs D - In B and C, the legs and arms stretch the most with some stretch in the spine. In D, the leg and the arm stretched a lot more and the spine less. The difference in stretching between B&C and D was 3 inches.

B&C vs E - In B and C, the legs and arms stretch the most with some stretch in the spine. In E, the legs stretched the most then the spine and then the neck. The difference in stretching between B&C and E was 0.75 inches.

If I had time, I would calculate the stretches for each part of the body.

E. For an elastic structure, the sample should return to its original state upon onloading, and the response to repeated loading should be identical. Did your Stretchy seem to return to its original state, or else be damaged by your testing ?

I would guess that it would get longer in time from continuous stretching, like how a rubber band stretches and breaks overtime.

(updated 2021.04.13)

xhibited ?decreasing, constant, increasing?constant stiffness as indicated by linear fit of Force vs Displacement data.

Table 2. Load vs Displacement of "Stretchy" (2 arm + 2 legs).

Lab 01C	**Stretchy Test**				
Date	7/127/2022	Start Time	8:30		
Name	Natasha S	End Time	9:18		
Scale	329				
Configuration	2 arms + 2 legs				
	Stretchy				
Object Description	**Postion**	**Postion**	**Measured Mass**	**Measured Mass**	**Force**
	[in]	**[mm]**	**[g]**	**[g]**	**[N]**
Resting	5	0	-25	25	0.25
	6	25	-52	52	0.51
	7	51	-66	66	0.65
Half	8	76	-82	82	0.80
	9	102	-94	94	0.92
Full	10	127	-106	106	1.04

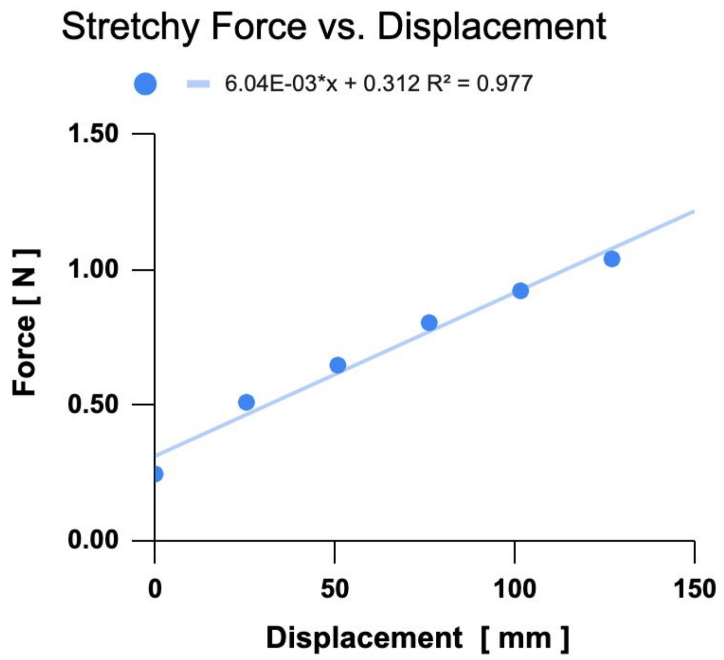

Figure 3. Stiffness test of "Stretchy" loaded between 2 arms + 2 legs.

(updated 2021.04.13)

DISCUSSION

4. Load vs Displacement Curve - "Toe" and "Linear" Regions

Tensile tests often have a Load vs Displacement behavior that varies with the extent of stretch. The "toe", "linear", and "failure" regions are often interpreted as reflecting biological structure behavior. The "toe" region is sometimes attributed to un-crimping of tissue, the "linear" region to linear elastic structures, and the "failure" region to gradual disruption of tissue micro-structures. Your test results on Stretchy may show a number of these behaviors.

A. Identify and characterize a mid-test region that is approximately linear. Give the beginning (x1, y1) and end (x2,y2) points of the linear region, and calculate the stiffness as the slope = (y2 - y1) / (x2 - x1).

(1) (x1, y1) = (51, 0.65)

(2) (x2, y2) = (102, 0.92)

(3) stiffness = (y2-y1)/(x2-x1) = 0.005 N/mm

B. How does the stiffness compare to that of a typical tendon (find, and provide reference to, a value on line) ?

The human tendon stiffness is 161 N mm^{-1}. (Maganaris, J Physiol. 1999 Nov 15; 521(Pt 1): 307–313. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2269645/)

The model stiffness was about 32200 times smaller than the stiffness of a human tendon?!

C. How did the initial test region (lower than the ~linear region) compare in slope ? Why might that be ?

Slope of initial test region: 0.0078 N/mm, which is higher than the linear region, which is unexpected. This could be due to measurement error or the material starts out stiff but then gets more elastic?

D. Did the linear region continue until the maximum value(s) of your test ? To what extent ? Why might that be ?

Yes, again it is unexpected. I might not have pulled long enough (to failure) because I was afraid of breaking it.

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Stretchy exhibited stiffness that varied with "boundary" conditions at fixture to extend between 1 arm + 1 leg or **.

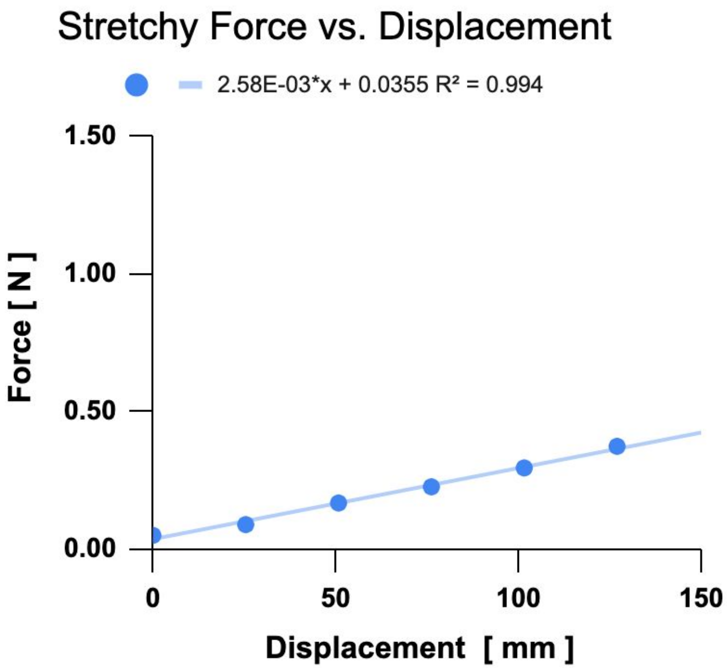

Figure 4. Stiffness test of "Stretchy" loaded by 1 arm + 1 leg.

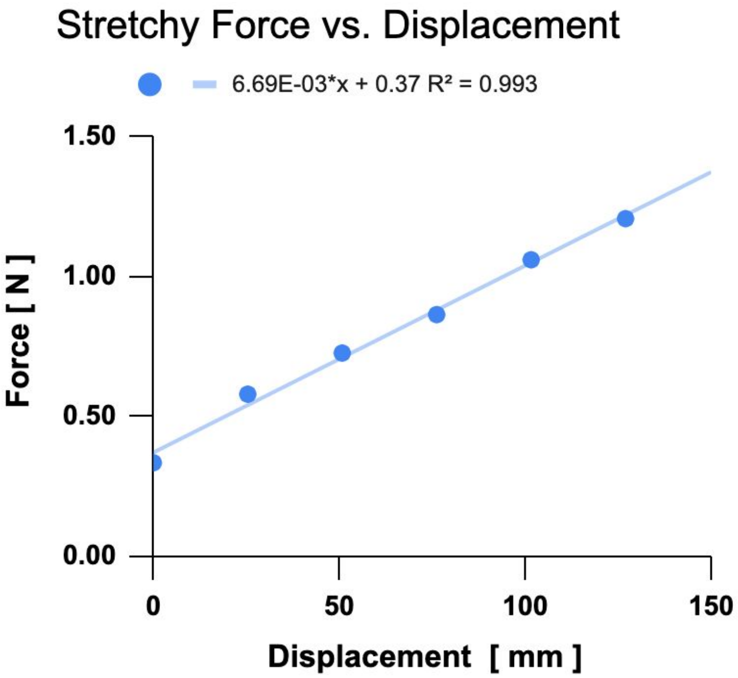

Figure 5. Stiffness test of "Stretchy" loaded by head stretch

(updated 2021.04.13)

DISCUSSION

5. Structural Stiffness Comparisons

Testing Stretchy by (Fig 3) 2 arms + 2 legs, vs (Fig 4) 1 arm + 1 leg, vs (Fig 5) (your choice), may reveal different overall and local stiffness behavior.

A. Compute the linear region stiffness values for your two other configurations.

(1) Fig 4: stiffness for 1 arm + 1 leg = (y2-y1)/(x2-x1) = 0.00270 N/mm

(2) Fig 5: stiffness for head stretch = (y2-y1)/(x2-x1) = 0.00631 N/mm

B. How do these stiffness values compare to that from Fig 3 ?

Figure 3 (2 arms / 2 legs) stiffness is 0.005 N/mm. The stiffness for one arm / one leg was significantly lower and the stiffness for the head stretch was significantly higher compared to the stiffness of the two arms / two legs.

C. Are the numerical values consistent with what you saw and interpreted from Fig 2 ?

Yes they are because it takes a lot less force to stretch one arm + one leg than two arms + two legs. It is also going to take more force to do the head stretch because it is only stretching two legs compared to the two arms + two legs, where both the arms and legs are very stretchy.

D. Biological samples a rarely homogeneous (the same everywhere) and more typically are inhomogeneous. Testing Stretchy exemplifies that. Describe where your various test results indicate inhomogeneity.

The left and right arms vs the left and right legs are different in stretchiness (non-symmetric). The different parts of the body have different stretchiness, like arm vs leg vs spine vs neck.