BioMechanics & MechanoBiology (BMMB)

Biomechanical Levers of the Body

Lab 4: Joints as Levers

Results Slide Template

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Table 1. Distance from edge of rail positions.

Slot Position	x, Distance From Edge	Delta x, Distance to next slot position	Extended Rail Slot Position	x, Distance From Edge	Delta x, Distance to next slot position
	[mm]	[mm]		[mm]	[mm]
0	0.0				
1	4.7	14.8	15	173.8666667	14.8
2	19.5		16	188.6666667	
3	29.6	14.8	17	198.7666667	14.8
4	44.4		18	213.5666667	
5	54.6	14.8	19	223.7666667	14.8
6	69.4		20	238.5666667	
7	79.8	14.8	21	248.9666667	14.8
8	94.6		22	263.7666667	
9	99.6	14.8	23	268.7666667	14.8
10	114.4		24	283.5666667	
11	124.7	14.8	25	293.8666667	14.8
12	139.5		26	308.6666667	
13	149.7	14.8	27	318.8666667	14.8
14	164.5		28	333.6666667	
	avg delta x (odd positions)	24.2			

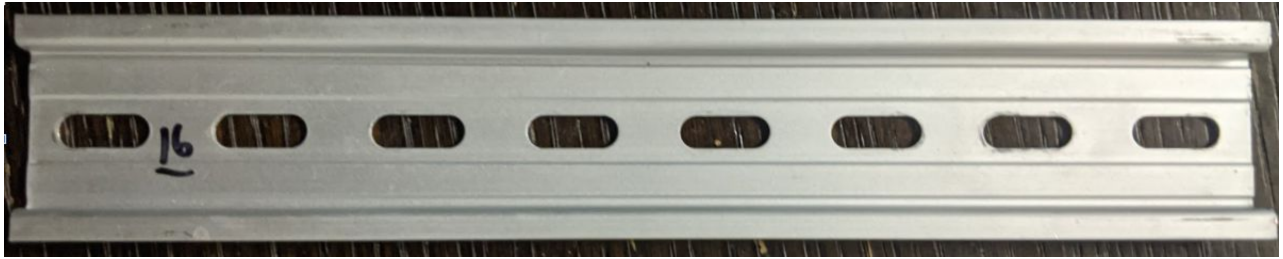

Figure 1. Standard Rail with ID showing.

Table 2. Component weights.

Lab 4	**Component Mass**		
Date	7/28/2022	Start Time	13:00
Name	Natasha S	End Time	13:30
Scale ID#	1378		
#	**Item**	**Mass [g]**	**Force [N]**
1	1 Bumper	19	0.186
2	2 Bumpers	29	0.284
3	3 Bumpers	40	0.392
4	4 Bumpers	49	0.481
5	Vise	230	2.256
6	Rail (no sleeve)	27	0.265
7	Hinge + Screw + Spacer + Wingnut	40	0.392
8	Rail + Hinge Assembly	74	0.726
9	Hook	1	0.010
10	Nut	1	0.010
11	Cup	3	0.029
12	Wingnut	1	0.010

RESULTS

1. Quantitative Modeling of Joint Loading. (setup 1A as head tilt; setup 1B as right hip stance)

A. Do your distance measurements seem approximately correct ? Explain !
It is a little off because when I measure the distance between slots 1 to 11, it is 129.0 mm. The chart approximates the distance to 124.7 mm. The error is because the chart is a calculation.

B. Considering your lever simulation, what rail position would approximate the distance from the fulcrum to the center of the body mass ? Explain !
For setup 1B, the fulcrum was at slot 7. The body mass was at slot 15. Rail 8 because the middle of the body mass was approximately one rail position from the outside of the fulcrum and stationed at 7. 15-7=8

C. Do your mass measurements seem approximately correct ? Explain !
They balance is not very accurate, so they seem approximately correct plus or minus a gram.

D. Considering your lever simulation, what factor would you multiply the weight of 1 bumper by in order to scale that up to (i) the weight of the head or (ii) the weight of the body ? Explain !
1 bumper = 19 grams. Multiply 1 bumper by scale factor of 384 to scale that to the weight of the head.
i) 1 lb = 454 grams so 10 lbs is weight of the head is 4540 grams, so the head weight is 240 times heavier than a bumper.
ii) 1 lb = 454 grams so 100 lbs body weight is 45400 grams, so the body weight is 2400 times heavier than a bumper.

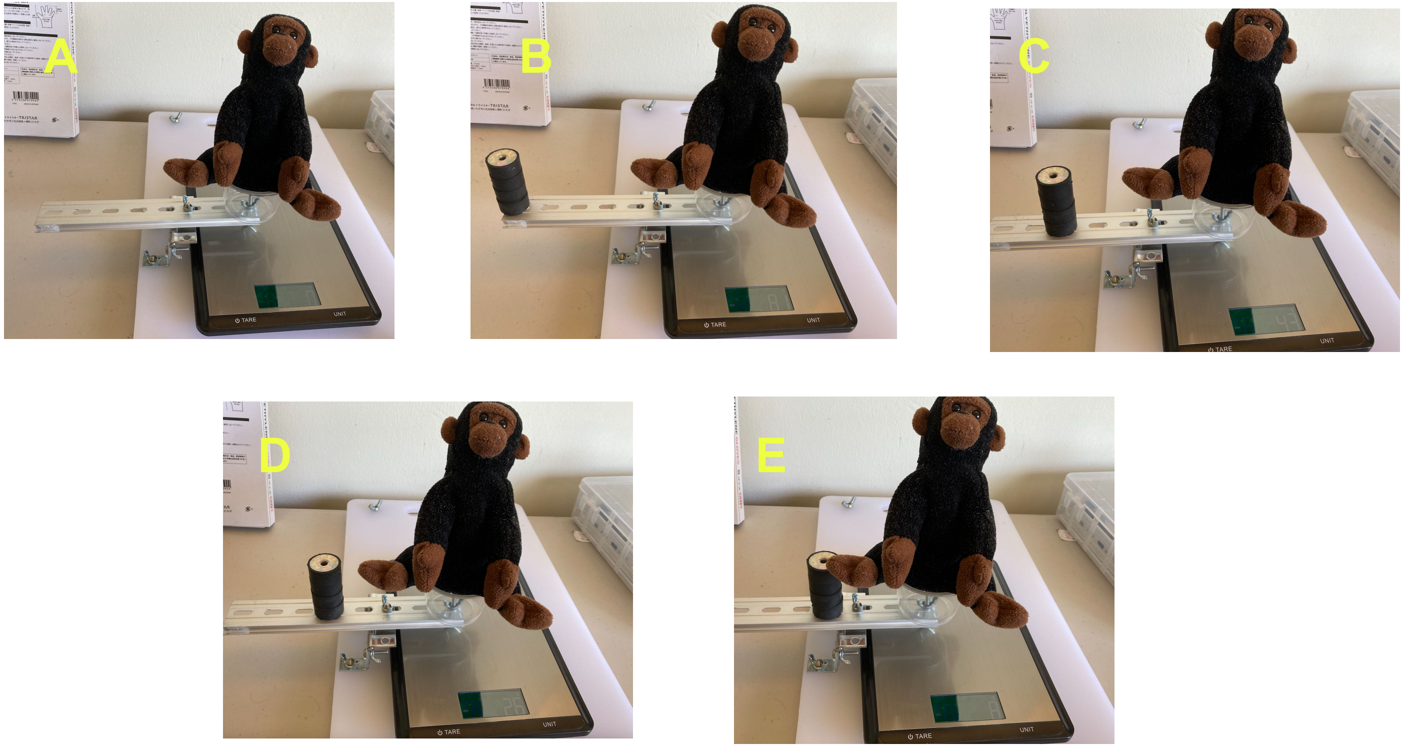

Figure 2. Photos of Lever 1A-Exp 1 setup at various states of loading. (A) Unloaded. **(B-E)** Weight moved sequentially along rail to positions **15,13,11, and 9**.

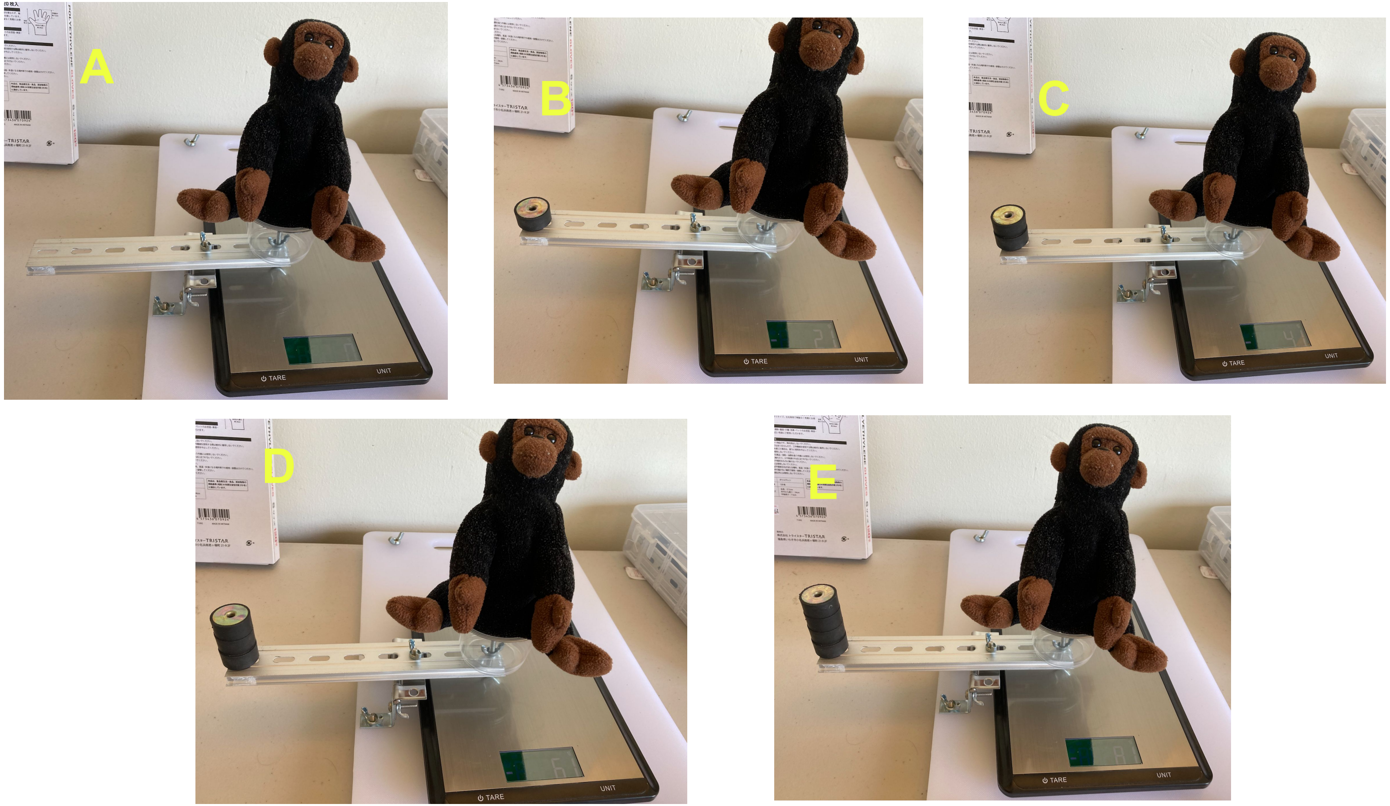

Figure 2. Photos of Lever 1A-Exp 2 setup at various states of loading. (A) Unloaded. **(B-E)** Weight sequentially increased at a rail position 15.

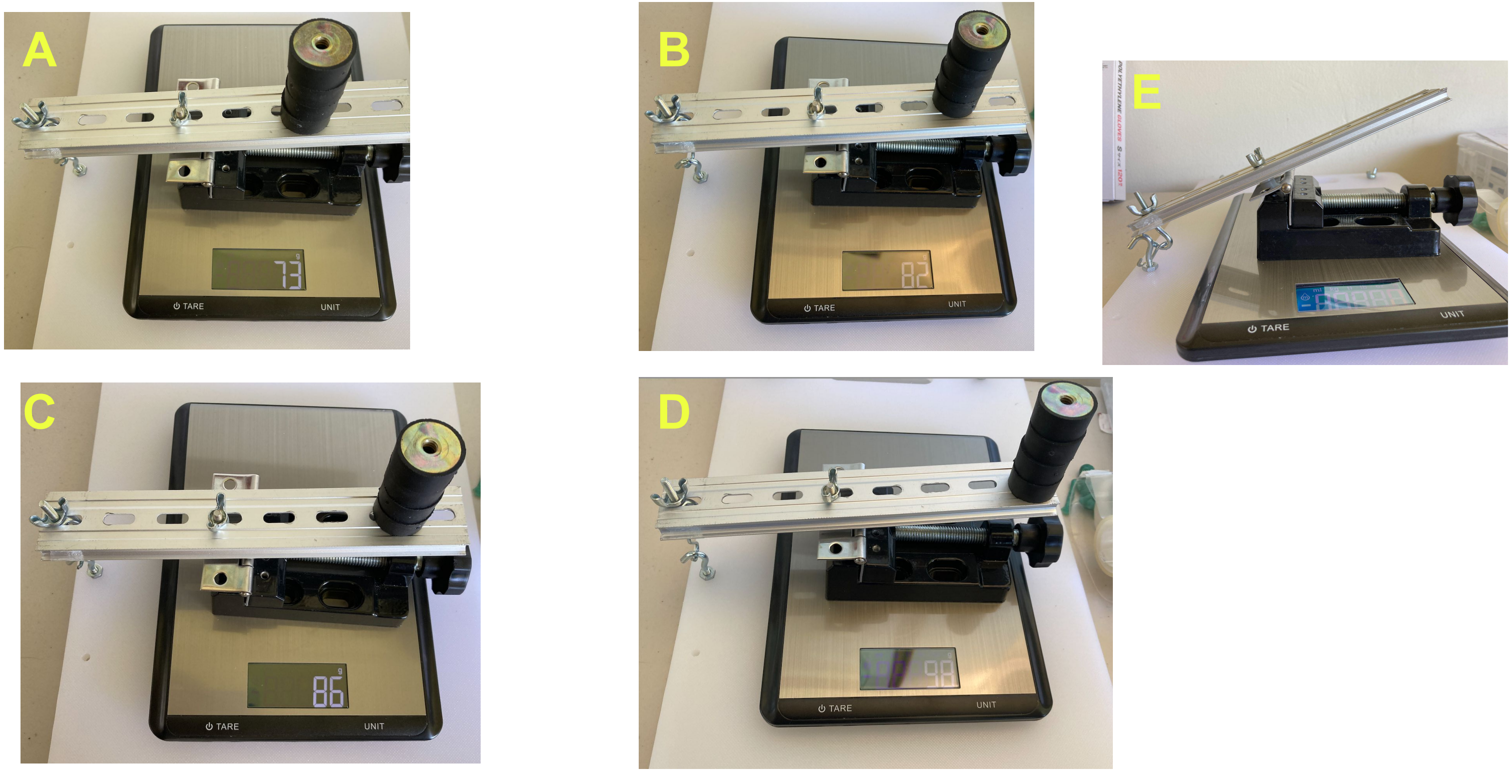

Figure 2. Photos of Lever 1B-Exp 1 setup at various states of loading. (E) Unloaded. **(A-D)** Weight moved sequentially along rail to positions **12,13,14, and 15**.

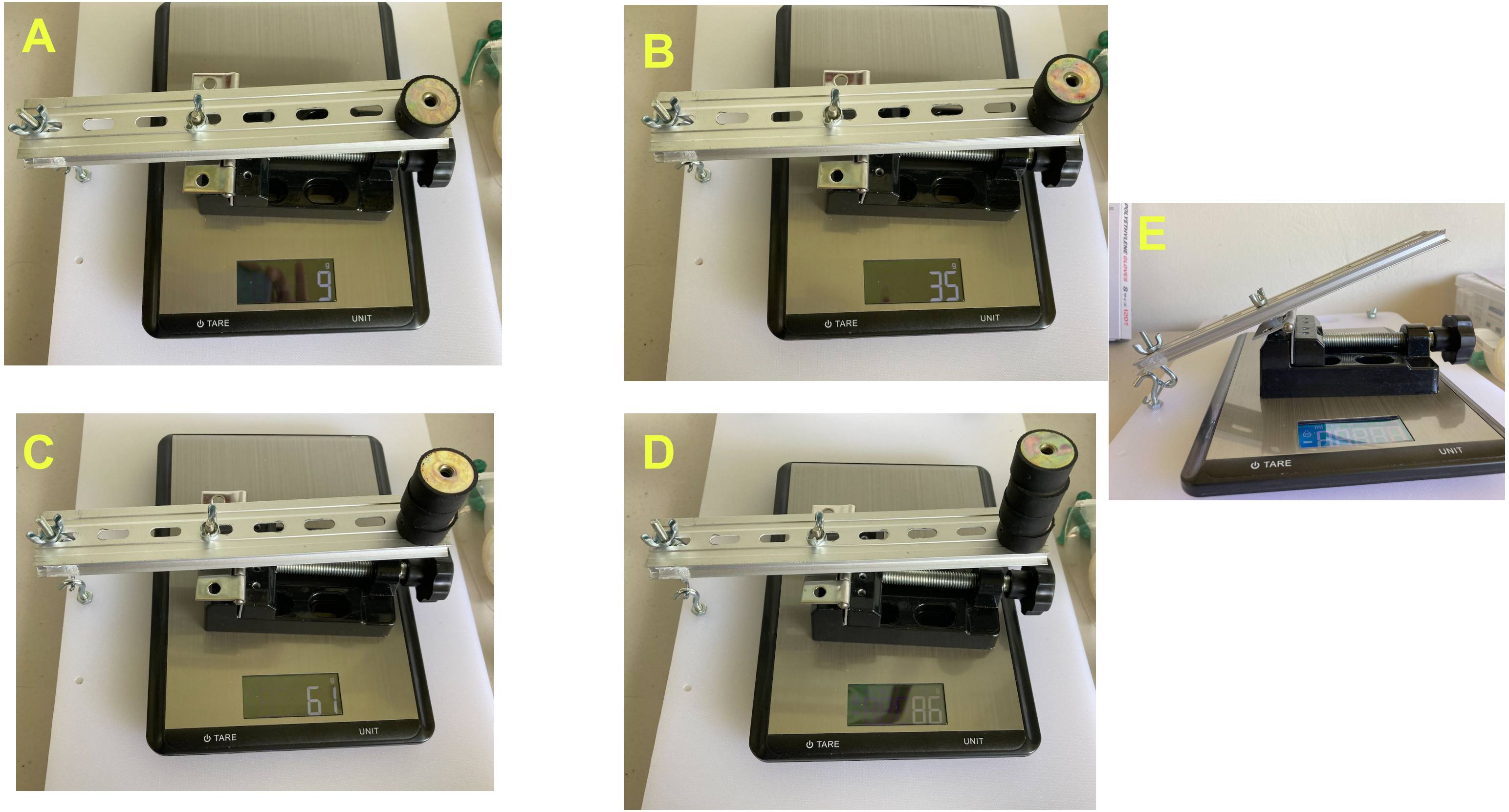

Figure 2. Photos of Lever 1B-Exp 2 setup at various states of loading. (E) Unloaded. **(A-D)** Weight sequentially increased at a rail position 15.

RESULTS

2. Lever experimentation setup. (setup 1A as head tilt; setup 1B as right hip stance)

A. Did you encounter any difficulties setting up the lever and use any special maneuvers ?
I did not encounter any difficulties while setting up the lever for both setup 1A and setup 1B.

B. What do you think might be sources of error in relating experiment to theory ? Explain !
For setup 1B, a big source of error was the unweighted measurement because it would tip over, so the zero weight condition was off. But for the experiment, I think it is still a constant offset.

For both setup 1A and 1B, there are many measurement errors including the accuracy of the scale and the measurements of the slots.

I kept the washers in the same order because they had different weights.
The center of mass is also an error because the f*d is going to be different than what we calculated it to be.

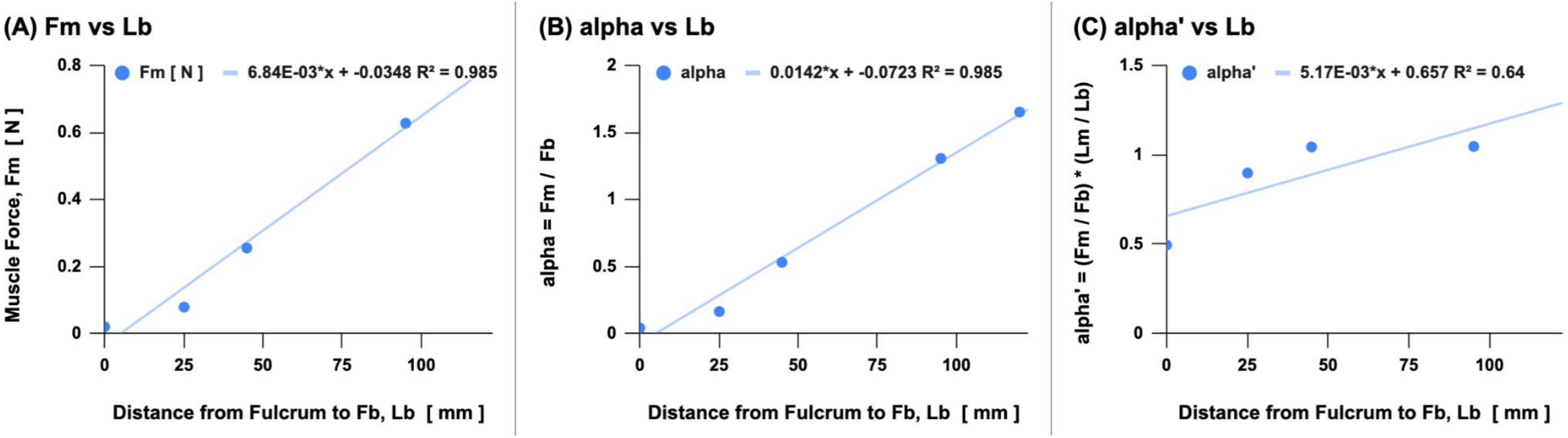

Figure 3. Lever 1A-Exp 1 Effects on Fm of Lb position (with constant Fb). Variation with Lb of **(A) Fm, (B) Fm normalized to Fb,** and **(C) Fm normalized to Fb, Lb, & Lm.**

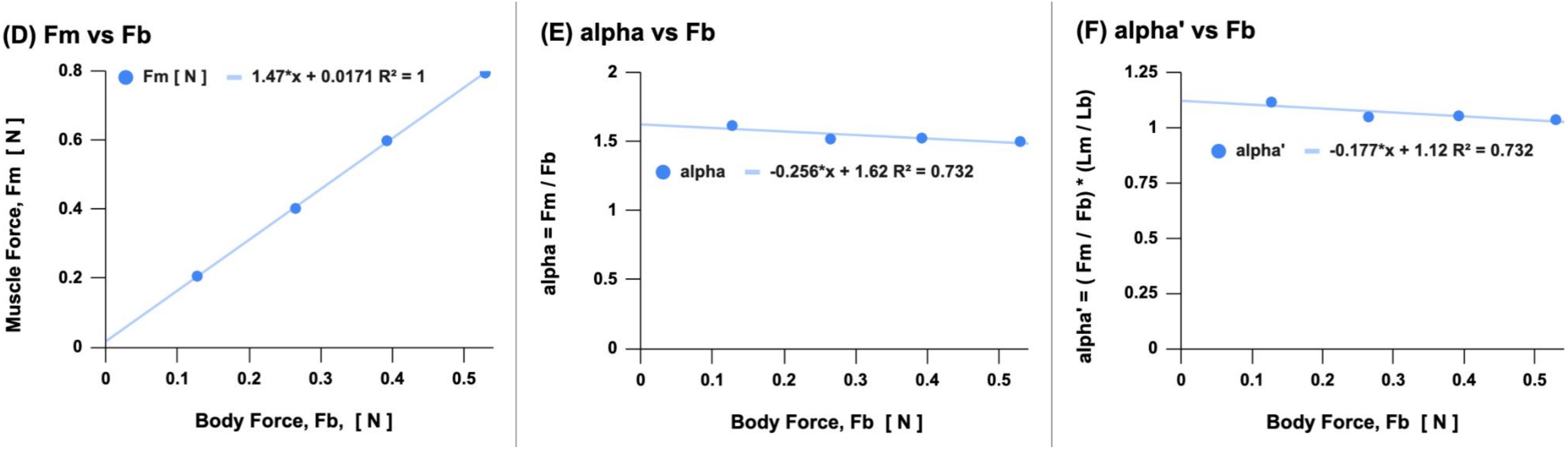

Figure 3. Lever 1A-Exp 2 Effects on Fm of Fb amplitude (with constant Lb). Variation with Fb of **(D) Fm, (E) Fm normalized to Fb,** and **(F) Fm normalized to Fb, Lb, & Lm.**

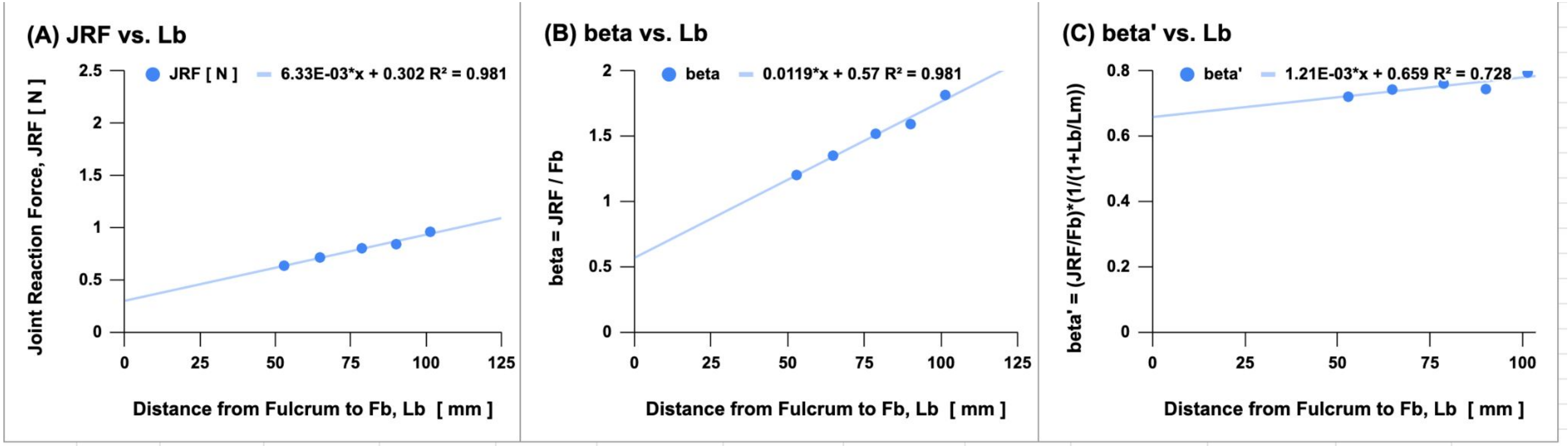

Figure 3. Lever 2A-Exp 1 Effects on JRF of Lb position (with constant Fb). Variation with Lb of **(A) JRF, (B) JRF normalized to Fb,** and **(C) JRF normalized to Fb, Lb, & Lm.**

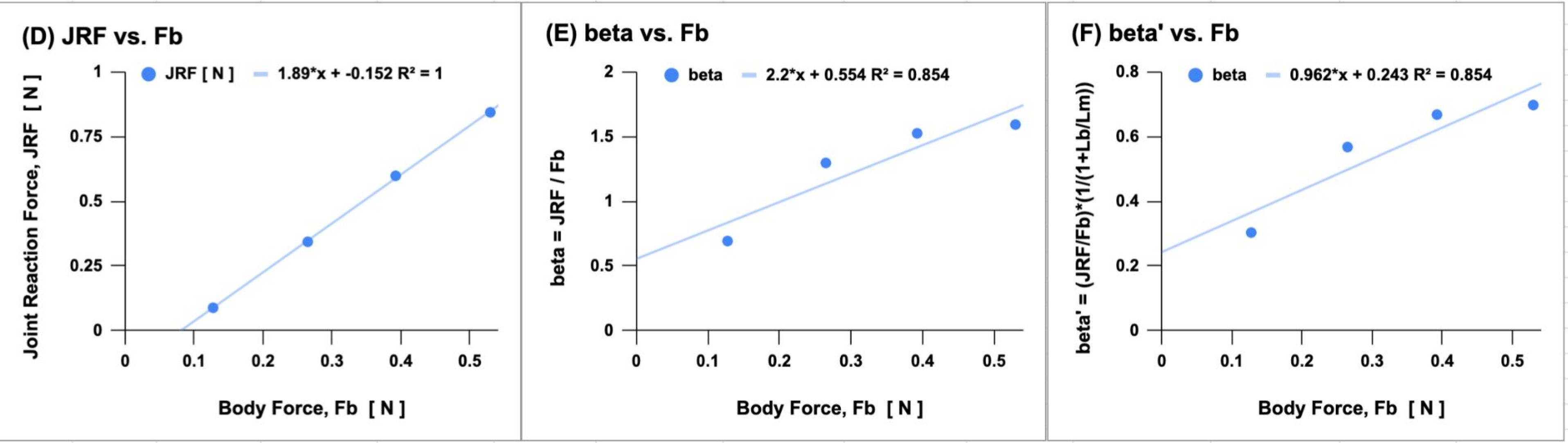

Figure 3. Lever 2A-Exp 2 Effects on Fm of Fb amplitude (with constant Lb). Variation with Fb of **(D) JRF, (E) JRF normalized to Fb,** and **(F) JRF normalized to Fb, Lb, & Lm.**

RESULTS

3. Interpreting Experiment in the context of Theory. (setup 1B as right hip stance)

A. For your Figure 3, panel A, what equation would you expect the relationship (Y vs X) to follow ? (JRF vs Lb)

Mathematically, JRF = Lb •(Fb / Lm) + Fb, so I would expect that the equation for this relationship is in the form y = mx + b (linear) because it is showing how as the distance from the fulcrum increases, the JRF also slowly increases.

B. For your Figure 3, panel A, linear fit, were (i) the slope and (ii) the intercept what you expected ? If not, what might be reasons for that ?

i) The slope should be Fb / Lm = 0.0067, but the graph shows 0.063, which is about 6% error.
ii) if Lb = 0, then JRF = Fb. So the intercept should be 0.53 (see table), but it is = 0.30, which is about 43% error.
There is always measurement error from the scale and the actual length varied from the calculated length.

C. Your Figure 3, panel B, is similar to panel A except the value is normalized. How does the plot of panel B help to provide additional information that is easier to see than what is shown in panel A ?

It is supposed to be easiest because the Force is normalized, so the slope is higher. Panel B is able to better provide information about other forces that could be applied in a similar situation, making it easier to compare the differences between those forces.

D. Your Figure 3, panel C, is similar to panels A and B, except the value is normalized further. What equation would you expect the relationship (Y vs X) to follow here ?

I would expect the figure 3 panel C to follow the equation β' = (JRF/Fb)•1/(1+Lb/Lm) = 1. The line should be equal to 1.

E. Your Figure 3, panel C, linear fit, were (i) the slope and (ii) the intercept what you expected ? If not, what might be reasons for that ?

i) I would expect a constant slope of 0 (measured was 0.001) and ii) the intercept should be 1 (measured was 0.24).
Measurement error and the zero weight was inaccurate because it touched the hook.

RESULTS

4. Physiological Implications.

A. Both muscle force and joint reaction force are difficult to measure in a living organism or person. How did the setups 1A and 1B enable measurement of these forces directly (in the simulation) ?
These simulations were a way to replicate the movements and restrictions in both the neck and the right hip. For the right hip, the bumpers acted as the body weight force, while fulcrum acted as the hip joint and the S-links act like the ligaments that keep the bones attached, and the Fm acted as the muscle force required to move joints? It is hard to completely isolate that joint, so it hinders the ability to measure these forces in a living organism.

B. Scaling is often needed to relate a model to an actual situation. Considering the lengths and masses, how would you scale your measurement to that of the actual force in a person ?
Look up the actual lengths and masses of the force in a person and then multiply the model of a situation by that number (ratios). For example, to model body weight with a bumper, 1 bumper = 19 grams.
i) 1 lb = 454 grams so 10 lbs is weight of the head is 4540 grams, so the head weight is 240 times heavier than a bumper. To model leg length with a rail, 1 rail = 175mm, so the length of a leg (my leg is about 900mm) is about 500 times longer than a rail.

In order to scale the measurement to that of the actual force in a person, we would need to scale our measurement up by a bit. I would first find real life substitutes for the parts of the lever in a person. Then I would scale each part up to the actual length of that biological part.

You could also do a computer simulation to model these forces.