# Lab 10: Biophysics

Name:

**PES 115 Report** Lab

## Objective

The purpose of this lab was to apply Newton's Laws to rigid bodies by studying the principle of equilibrium and torque. We used a model of the human bicep to study the resultant forces due to torque on a rigid body.

**This day has been a long time coming, but it is finally time for you to leave the nest and try writing the reports on you own!**

## Data and Calculations

### Part A:

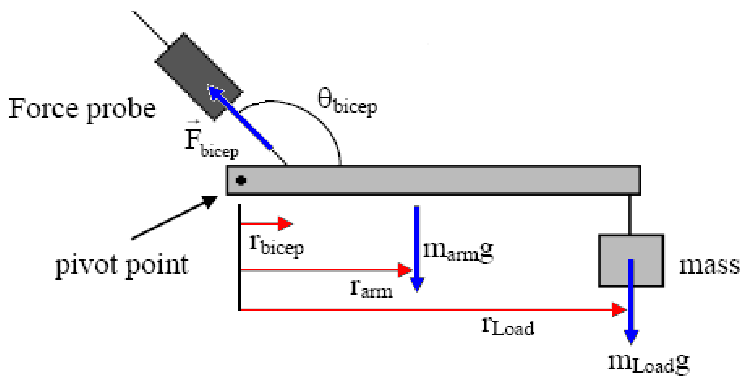


*Figure 1: Experimental Setup of the Bicep used to Measure Force*

Before beginning, I measured the various distances and masses I needed for the experiment (shown in the figure above). The following table provides the values I obtained during the experiment:

| $r_{bicep}$ (mm) | $r_{arm}$ (mm) | $r_{load}$ (mm) | $m_{arm}$ (g) | $m_{load}$ (g) |
|---|---|---|---|---|
| 85 | 227.5 | 430 | 52.3 | 18.4 |

Next, after calibrating the Force sensor, I took 8 measurements of the angle of theta and the force measured by the sensor (due to the orientation and directions of the torque established in the rigid body). We were instructed to measure from 90-degrees to 180-degrees; however, any

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angles less than 106 were hard to get, since I couldn't keep the "arm" horizontally level – nor bring the force sensor close enough to the system.

| Theta [Deg] | Force [N] |
|---|---|
| 106 | 2.223 |
| 115 | 2.285 |
| 122 | 2.458 |
| 135 | 2.853 |
| 143 | 3.230 |
| 154 | 4.045 |
| 165 | 6.113 |
| 170 | 9.040 |

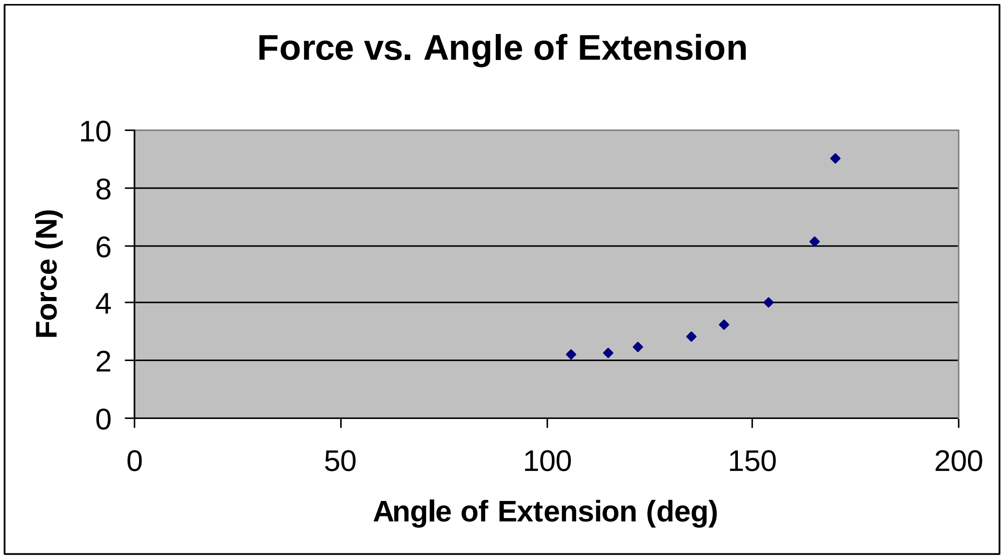


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*Figure 2: Measured Force versus Angle between Arm and Bicep*

To attempt to verify the data, I held my Physics textbook with my (good) arm bent (90-degrees in our coordinate frame). This wasn't a very difficult thing to do. I then held it with my (good) arm fully extended (180-degrees in our coordinate frame). I could only sustain holding the book for a few seconds, before my (good) arm got sufficiently tired. Not only did my bicep get tired, but my shoulder and triceps were exhausted as well. This seems to support the data collected.

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It's interesting to note that Physical Therapists and Orthopedic Doctors measure the co-angle to the angle we measured (with a goniometer). That is to say, when the arm is fully extended, they give this the angular measurement of 0-degrees. Likewise, when the arm is fully flexed, a healthy human (with full range of motion) can typically flex up to 150-160 degrees. The reason they do this, is because of the flexion limitation of the human body. Since people cannot flex past 160-degrees, it's silly to make that the 0 mark. ☺

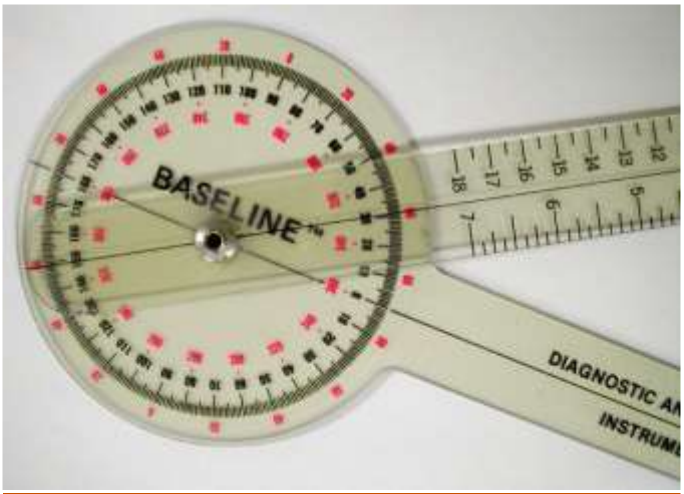


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*Figure 3: Example of a Goniometer used by Physical Therapists and Orthopedic Doctors (Notice its reading: 150-degrees of flexion – see the number in the bottom left corner.)*

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## Additional Questions

- Next, we ~~question 1~~

picked the following three sets of Force and Angle. We wanted to calculate the theoretical values using the numbers we measured and compare this to the values measured via the force sensor. We chose the following three values from our measurements:

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| Theta [Deg] | Force [N] |
|---|---|
| 115 | 2.285 |
| 135 | 2.853 |
| 165 | 6.113 |

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In order to calculate the theoretical values, we used the following equation and measurements obtained during the lab (notice that we converted the measured values into SI-units):

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$$F_{bicep} = \frac{r_{load} m_{load} g + r_{arm} m_{arm} g}{r_{bicep} \sin(\theta_{bicep})}$$

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| $r_{bicep}$ (m) | $r_{arm}$ (m) | $r_{load}$ (m) | $m_{arm}$ (kg) | $m_{load}$ (kg) |
|---|---|---|---|---|
| 0.085 | 0.2275 | 0.43 | 0.0523 | 0.0184 |

## Calculate $F_{bicep}$ for θ = 115°

$$F_{bicep} = \frac{(0.43\,m)(0.0184\,kg)\left(9.81\frac{m}{s^2}\right) + (0.2275\,m)(0.0523\,kg)\left(9.81\frac{m}{s^2}\right)}{(0.085\,m)\sin(115^o)}$$

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$$\boxed{F_{bicep} = 2.522693\,N}$$

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## Calculate $F_{bicep}$ for θ = 135°

$$F_{bicep} = \frac{(0.43\,m)(0.0184\,kg)\left(9.81\frac{m}{s^2}\right) + (0.2275\,m)(0.0523\,kg)\left(9.81\frac{m}{s^2}\right)}{(0.085\,m)\sin(135^o)}$$

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$$\boxed{F_{bicep} = 3.233367\,N}$$

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## Calculate $F_{bicep}$ for θ = 165°

$$F_{bicep} = \frac{(0.43\,m)(0.0184\,kg)\left(9.81\frac{m}{s^2}\right) + (0.2275\,m)(0.0523\,kg)\left(9.81\frac{m}{s^2}\right)}{(0.085\,m)\sin(165^o)}$$

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$$\boxed{F_{bicep} = 8.833724\,N}$$

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## Error Calculations

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Finally, we calculated the %difference between the experimental and theoretical values for the Forces at the different angles.

$$\%\ difference = \frac{|F_{Theory}| - |F_{Measured}|}{|F_{Theory}|} x100\%$$

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**$F_{bicep}$ for θ = 115°**

$$\% \ difference = \frac{|2.522693\,N| - |2.285\,N|}{|2.522693\,N|} x100\% = 9.42\%$$

**$F_{bicep}$ for θ = 135°**

$$\% \ difference = \frac{|3.233367\,N| - |2.853\,N|}{|3.233367\,N|} x100\% = 11.76\%$$

**$F_{bicep}$ for θ = 165°**

$$\% \ difference = \frac{|8.833724\,N| - |6.113\,N|}{|8.833724\,N|} x100\% = 30.80\%$$

**<Go see the Lab 10 Comments document for the answer to the deltoid problem. We'll analyze another system – for the sake of *personal* interest.>**

Now for some practical application of the data you just collected. Assume you (or someone you know) were in a bike accident and shattered your (or their) left elbow into 35+ pieces. After reconstructive orthopedic surgery, considering the pieces that were recoverable, the elbow might look like the following:

*Figure 4: Example of Bill's Reconstructed Shattered Left Humorous (Elbow)*

Since the Bicep and Triceps unattached from the forearm bones during the accident, they had to be reconnected to the Radius and Ulna. The attachment has the limitation that it will only sustain 1.5 kilo-Netwons of Force on the Bicep, before becoming unattached again (since medical



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treatment is never as good as the original natural equipment). Using the information you just collected, what will be the patient's (Bill's) maximum load weight (in pounds) if his current active range of motion is 15-degrees on extension (measured with the goniometer) to 115-degrees on flexion (measured with the goniometer) with these limitations? (Remember that the goniometer measures the co-angle to the angle we measured in the formula we used.)

| **$r_{bicep}$ (m)** | **$r_{arm}$ (m)** | **$r_{load}$ (m)** | **$m_{arm}$ (kg)** | **$F_{bicep}$ (N)** | **$Theta_{Max}$ (deg)** |
|---|---|---|---|---|---|
| 0.10 | 0.25 | 0.60 | 0.045 | 1500.0 | $180^{o}$-$15^{o}$ = $165^{o}$ |

$$F_{bicep} = \frac{r_{load} m_{load} g + r_{arm} m_{arm} g}{r_{bicep} \sin(\theta_{bicep})}$$

Solve this for the mass of the load, since this is what we're trying to find:

$$m_{load} = \frac{F_{bicep} r_{bicep} \sin(\theta_{bicep}) - r_{arm} m_{arm} g}{r_{load} g}$$

$$m_{load} = \frac{(1500\,N)(0.1\,m)\sin(165^{o}) - (0.25\,m)(0.045\,kg)\left(9.81\frac{m}{s^2}\right)}{(0.6\,m)\left(9.81\frac{m}{s^2}\right)} = 6.58\,kg$$

$$\boxed{0\,kg \le m_{load} \le 6.58\,kg}$$

The conversion from pounds to kilograms is:

1 pound [lb] = 0.453592 kilogram [kg]

Thus in pounds, this corresponds to:

$$\boxed{0\,lbs \le m_{load} \le 14.5\,lbs}$$

Hence, if Bill lifts anything more than 14 pounds (the equivalent of six physics books) with his "bad" arm (at full range of motion extension), there is a pretty substantial risk that the force on the bicep will cause the bicep to become unattached. This would not be a pleasant situation to experience!

**☹ Poor Bill! ☹**



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***(Just as a gee-wiz: Right now in Physical Therapy, in addition to range of motion extension [to break out of the 25-110 degree active range at which I am currently], they have me doing bicep/deltoid strength training by lifting a 4lb ball at full arm extension 30 times.)***

## Conclusion

You are intelligent scientists. Follow the guidelines provided and write an appropriate conclusion section based on your results and deductive reasoning. See if you can think of any possible causes of error.

** NOTE: There are several components of error which could significantly modify the results of this experiment. Some of these are listed below:

- Parallax
- Ruler measurement
- Angle measurement w/ protractor (should have used a goniometer)
- Mass measurement
- Force sensor calibration
- Sensor Alignment
- Other …

A few of the potential errors listed above may be applicable to YOUR experiment.

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