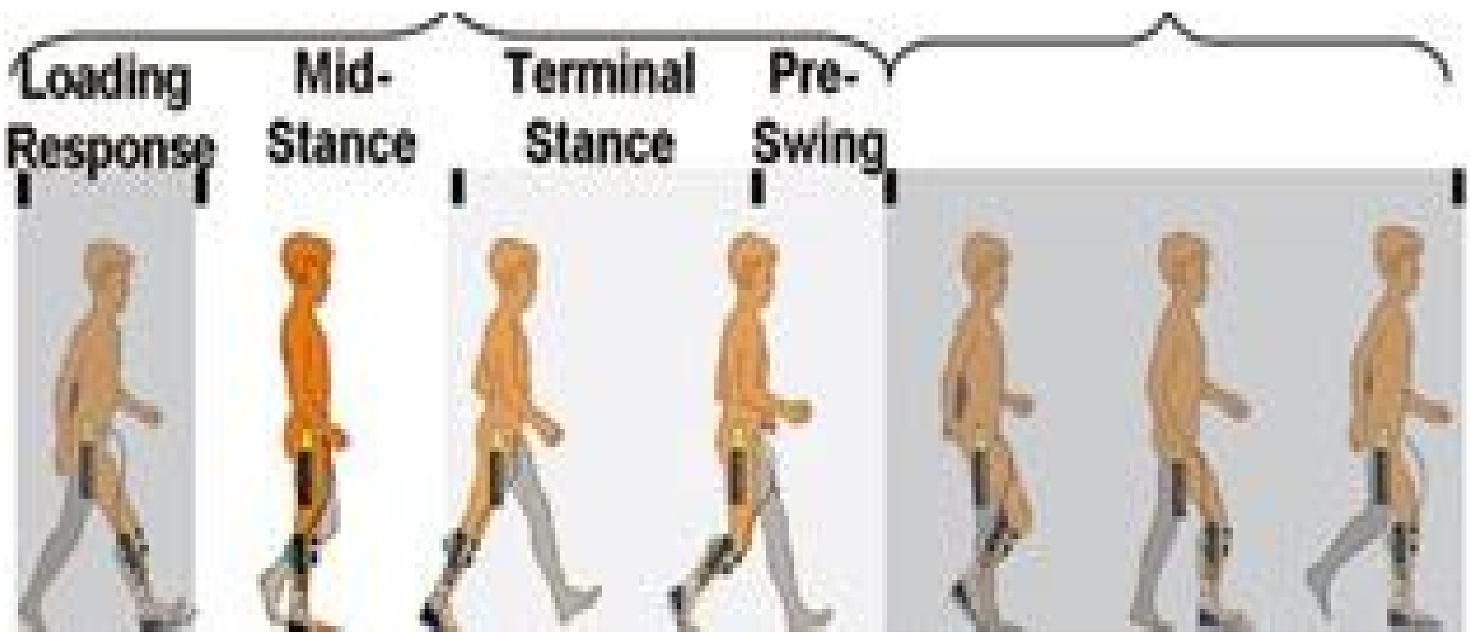
Gait Analysis of walking humans



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Test subjects: Lara Fleischhauer, Lara Glendening, Caitlin Dwyer, and Ben Drogin
Test Dates: September 25 - October 9, 2018

Abstract
In our experiment, we determined the relationship between height and gait frequency in walking humans. We began by downloading a walking app named “Physics Toolbox Accelerometer”. We then taped a phone, with the downloaded app, to our chests to create a central axis and performed three trials per person where we walked 545 meters. During the trials, we recorded the data obtained from the app, the time it took to walk the set distance, the amount of steps, and the persons foot size, height, and stride length. From our data we observed that Ben, who is the tallest, had the highest gFy (gravitational force downward) and Lara F., who is the shortest, had the smallest gFy. In addition we found that Lara F. had the highest gFx, meaning she had the highest gait frequency. Therefore we concluded that as height increases, horizontal gravitational force decreases, meaning the taller the person is, the smaller their resulting gait frequency is and the larger their stride length is. After concluding this, we were able to produce an equation for predicting other people’s gait frequencies as follows : =IF(B2>0.1, "short", IF(B2<0.1, "tall")). This predictive model categorizes people as either short or tall based on the analysis of their gFx. We tested this equation on each person’s three trials and found it to be successful. Although the equation did not work for Lara G.’s second trial, this was due to human error as she took 8 steps instead of 7 like her other trials. This difference in steps and her height of 173 cm tall, which is very close to our dividing value, 170 cm, produced a slight increase in her gait frequency that portrayed a gait frequency of someone below 170 cm in height. However without this one skewed result, our equation worked for all other trials.

Gait Analysis Lab
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Introduction

Gait analysis is the study of the study of animal movement. More specifically, for this report it is defined as the study of the stride of a human as they move their limbs. There are many applications for gait analysis, including medical diagnosis, forensic identification of people, and chiropractic uses. When graphed, people's gaits show up as waves. Below is a sample graph of a person's gait, as well as formulas for calculating the frequency and wavelength of these waves.

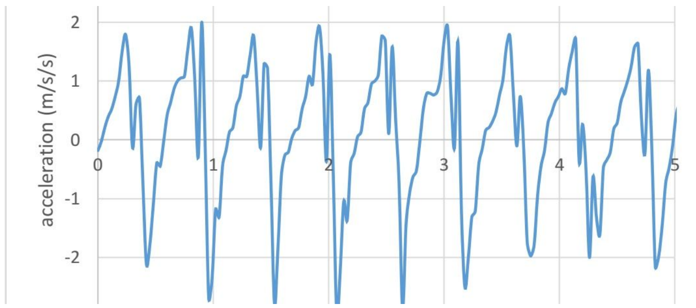

Figure 1: Nice Graph of Walking Data

Formula for frequency: ***f* (frequency) = 1 / *T* (period).**

f* = *c* / *λ = wave speed ***c*** (m/s) / wavelength ***λ*** (m).

Formula for time: ***T* (period) = 1 / *f* (frequency).**

Formula for wavelength: ***λ* (m) = *c* / *f***

λ = ***c* / *f*** = wave speed ***c*** (m/s) / frequency ***f*** (Hz).

In this experiment, graphs and spreadsheets of collected data will be used to answer the driving question of the experiment: "How does height affect gait in humans?" This question will be answered using data that shows the force of each person's gait in the x, y, and z directions. We hypothesize that taller people will take larger steps, so they will take fewer steps per trial than shorter people.

Method

We downloaded an app that measures walking data. We each walked a preset distance three times to collect data for multiple trials. We recorded the time it took to walk the distance, the amount of strides, which foot the walker started with, their stride length, and their height, leg length, and shoe size. We also saved the data recorded by the app.

The "apparatus" in this experiment was the app, Physics Toolbox Accelerometer. We found the recording axis after experimenting with the phone. A second part of the apparatus was duct tape, which we used to tape the phone to our chests to secure it for the walking trials. The app shows a line on the screen that goes up and down based on the motion of the walker. To start the recording of the data, we pressed a button on the screen, then pressed it again when we stopped walking. The apparatus then saved our data as a .CSV file, which we then uploaded to Google Sheets for analysis.

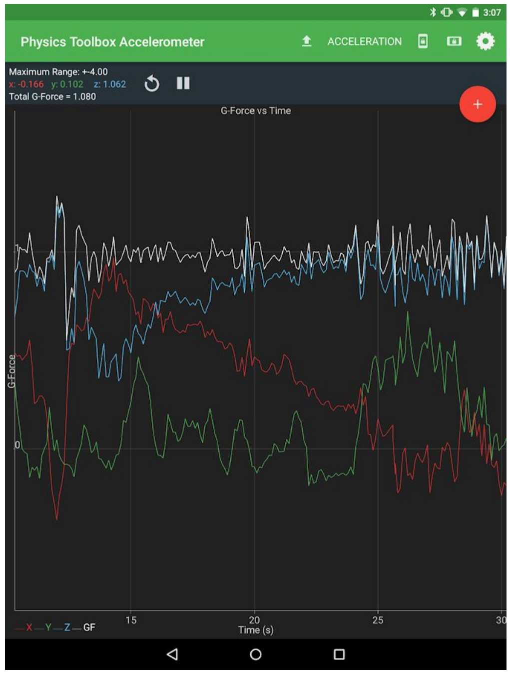

Figure 2: An image of the apparatus' screen

A list of the equipment used in this experiment and their uncertainties are shown in Table 1.

Equipment	Uncertainty
Physics Toolbox Accelerometer App	+/- 0.05
Duct Tape	n/a
Meter Stick	+/- 0.1 cm
Phone Timer	+/- 0.005 s

Table 1: Equipment

Procedure:

After finding the axis on the phone, each group member taped the phone to their chest and walked 545 centimeters with the app recording, counting their steps and remembering which foot they started with. They were also timed on a phone stopwatch, and their stride length was measured in centimeters. This process was repeated two more times. After each group member had done three trials, additional information was taken: height, leg length, and shoe size. All of this information was combined into a table and used in conjunction with the data from the Physics Toolbox Accelerometer app to analyze each person's walking data.

Results

After completing all of our testing we neatly recorded all of our data in four different data tables. Tables 2, 3, 4, and 5 show the different data that we collected throughout this experiment. We used the data collected by our app to calculate the average gFx, gFy, and gFz for each person. We then graphed these in Figures 3, 4, and 5. As shown by Figure 4 Ben had the highest gFy during the third trial. This is because he is the tallest person in our group which means that he has the most amount of gravitational force pushing down on his body. We also found that Lara F has the smallest gFy value which is due to her being the shortest person in our group. We also found that Lara F (the shortest person in our group) had the highest gFx. This means that she had the highest gait frequency, so she took more steps than the other test subjects in the same walking distance.

Ben - walking				Average
Trial	1	2	3	
distance (cm)	545	545	545	545
step count	8	7	7	7.333333333
height	183	183	183	183
leg length	108	108	108	108
shoe size	11.5 m	11.5 m	11.5 m	11.5m
time (sec)	4.83	4	4.08	4.303333333
starter foot	left	left	left	left
stride length (cm) (heel to toe)	95	100	99	92

Table 2: Ben

Caitlin - walking				Average
Trial	1	2	3	
distance (cm)	545	545	545	545
step count	7	8	8	7.666666667
height	176	176	176	176
leg length	110	110	110	110
shoe size	8.5 w	8.5 w	8.5 w	8.5w
time (sec)	4.83	4.59	4.56	4.66
starter foot	left	left	left	left
stride length (cm) (heel to toe)	82	80	81	78.33333333

Table 3: Caitlin

Lara F				Average
Trial	1	2	3	
distance (cm)	545	545	545	545
step count	9	9	9	9
height	164	164	164	164
leg length	98	98	98	98
shoe size	6.5w	6.5w	6.5w	6.5w
time (sec)	5.56	4.95	4.66	5.056666667
starter foot	right	right	right	right
stride length (cm) (heel to toe)	75	76	76	70

Table 4: Lara F

Lara G				Average
Trial	1	2	3	
distance (cm)	545	545	545	545
step count	7	8	7	7.333333333
height	173	173	173	173
leg length	107	107	107	107
shoe size	9w	9w	9w	9w
time (sec)	4.65	4.57	4.59	4.603333333
starter foot	right	right	right	right
stride length (cm) (heel to toe)	83	78	82	82

Table 5: Lara G

	Ben	Caitlin	Lara G	Lara F
Avg gFx	-0.04720649459	-0.02957265522	0.08199926847	0.1599234478
Avg gFy	0.9914079933	0.9982192867	0.9956488661	0.9786219875
Avg gFz	-0.03832472939	0.06571796565	0.03763935625	0.1178552985

Table 6: Average Gravitational Force in each direction on each person

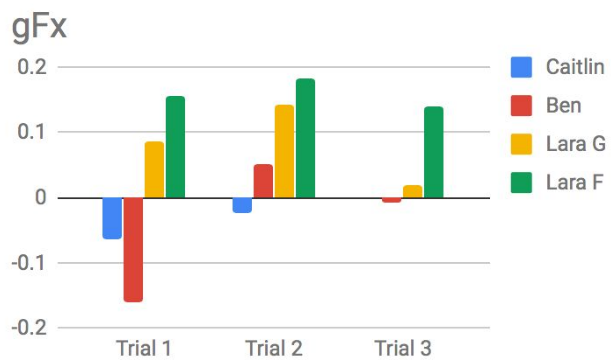

Figure 3: Average Horizontal Gravitational force

Note: Caitlin's data is on trial 3 of the gFx graph, but the bar is too small to see. That bar has a value of 0.0016.

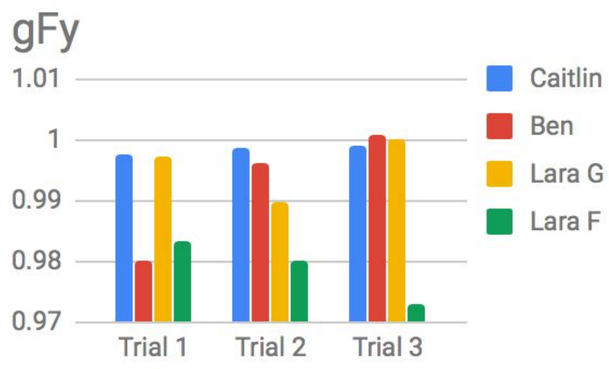

Figure 4: Average Vertical Gravitational force

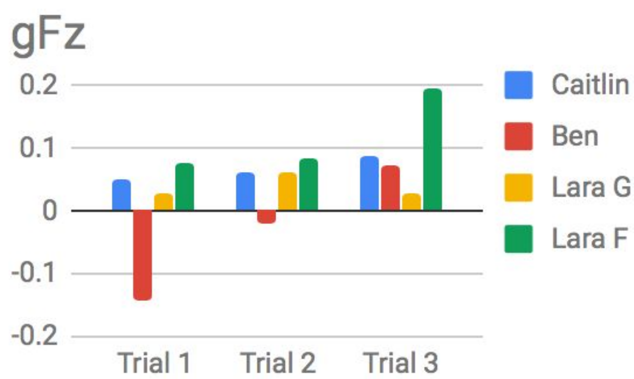

Figure 5: Average Forward Gravitational force

Discussion

Our driving question was determine the relationship between height and gait frequency in walking humans. Based on the data we collected we found that as height increases the horizontal gravitational force (gFx) decreases. This means that the taller a person is the smaller their gait frequency is, which confirms our hypothesis that taller people take fewer steps per trial than shorter people.

We came up with a model to predict this using an "if" statement on a spreadsheet. We divided people into two categories: short (under 170 cm) and tall (170 cm and above). We came up with a formula on a spreadsheet that analyzes the person's gFx and places them in one of the two categories. The model can be seen below:

```
=IF(B2>0.1, "short", IF(B2<0.1, "tall"))
```

Person	Trial 1	Trial 2	Trial 3
Caitlin	tall	tall	tall
Ben	tall	tall	tall
Lara G	tall	short	tall
Lara F	short	short	short

Figure 6: Prediction model and table created by the model

The way this model works is by analyzing the data in a certain cell, determining the value in that cell, and assigning a cell in a table a word value based on the numerical value in the original cell. In this specific formula, the cells are assigned a word based on if their numerical value is greater than or less than 0.1. If it is greater than 0.1, the formula writes “short”. If it is less than 0.1, the formula writes “tall”. We typed out the formula for the B2 cell in a spreadsheet of all of the averages of gFx for each trial, then used cell references to make the model apply to each cell with a value in it.

The model worked very well in almost every case, except for Lara G’s second trial. However, that trial is the result of human error. In this trial, Lara took eight steps, while she took seven in both of the other trials. Her stride length was also shorter than her normal strides. Since she is 173 cm tall, which is close to 170 cm (our dividing value), this slight increase in gait frequency, which differs from her normal gait, was enough to make her gait seem like the gait of someone below 170 cm. Excluding that skewed trial, the model predicted all the test subjects’ height correctly.

Throughout this experiment there were many possible areas for error. The biggest was the way that we used the phone to test our gait. We had to make sure that we all used the phone in the exact same way. This means that we had to place it on the same part of our bodies as each team member and it had to be placed on the same area for every trial. Each person also had to keep it sturdy the same way for example if one person duct taped it to their stomach, then everyone had to do the same thing. If at any point the phone was slightly off or less sturdy it could alter our results. This is where our group could have run into errors as we chose to put the phone into our pants, which means that it may have been more sturdy for some people than for others. Another possible error could have been in starting and stopping our app. Since it was on our body, we started the app as we took the first step and stopped the app after completing our last step. If at any point any of us started the app too early or stopped the app too late then errors in our data could appear. Another possible source of error came from the fact that we knew our gait was being recorded, which could have led us to unconsciously alter our gait. This could have skewed our results, as seen in Lara G’s second trial. The final area for error could have been in timing the person walking as we did not have the same person recording the time for every person. Another issue with timing could have occurred as we started and stopped the timer because we started it as the test person took their first step and finished their last step. If at any time the timer started the timer too early or stopped it too late then our results could be off.

Overall we found that the shorter the test walker the higher the gait frequency. We also found that the taller the test walker the higher the vertical gravitational force.

For future testing we would make our results stronger by using different test subjects. Ideally these test subjects would have a larger gap in height than we had in our group. We would also use more test subjects. We would use 12 test subjects , 3 around similar heights each. By using more test subjects who have larger height gaps we would be able to see the relationship between height and gait frequency more clearly. To make our test results more accurate we would ensure that the phone has the same sturdiness for each test and that we have the same timer time for each subject. We would also run more than three trials and find the average of those as outliers would appear more presently with more trials. For example we would be able to see outliers much clearer when completing five to ten trials than by completing three. By ensuring that we have more data results that are more accurate than our previous results we would be able to explain the relationship between height and gait frequency in walking humans more accurately and clearly.

References

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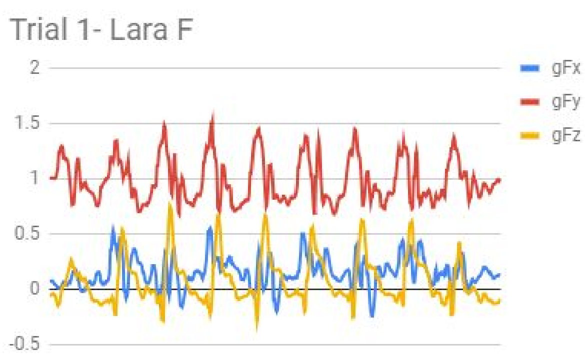
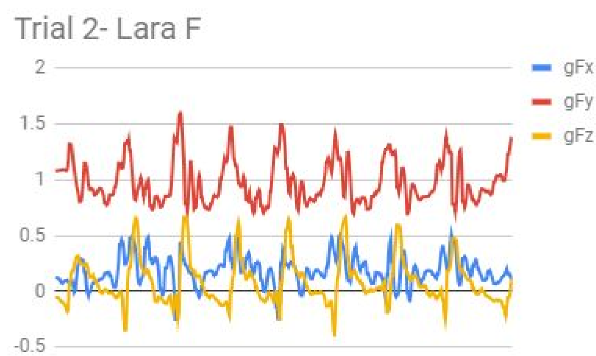
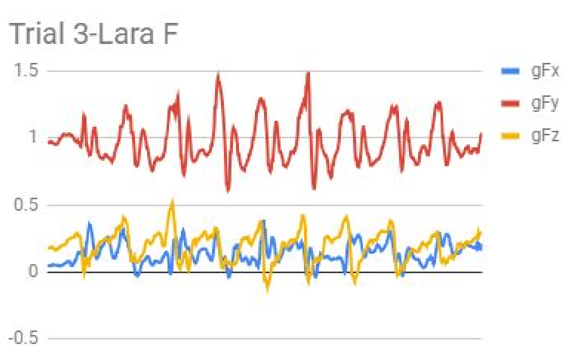
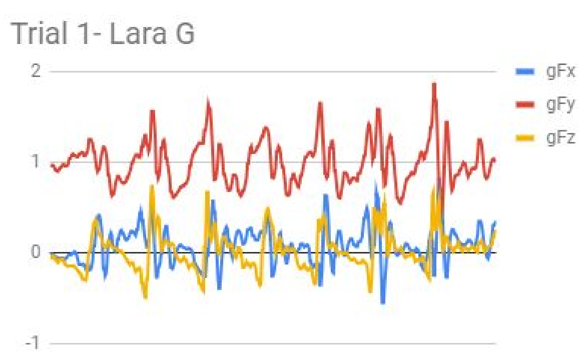
Appendix

Graphs of all the data from each trial:









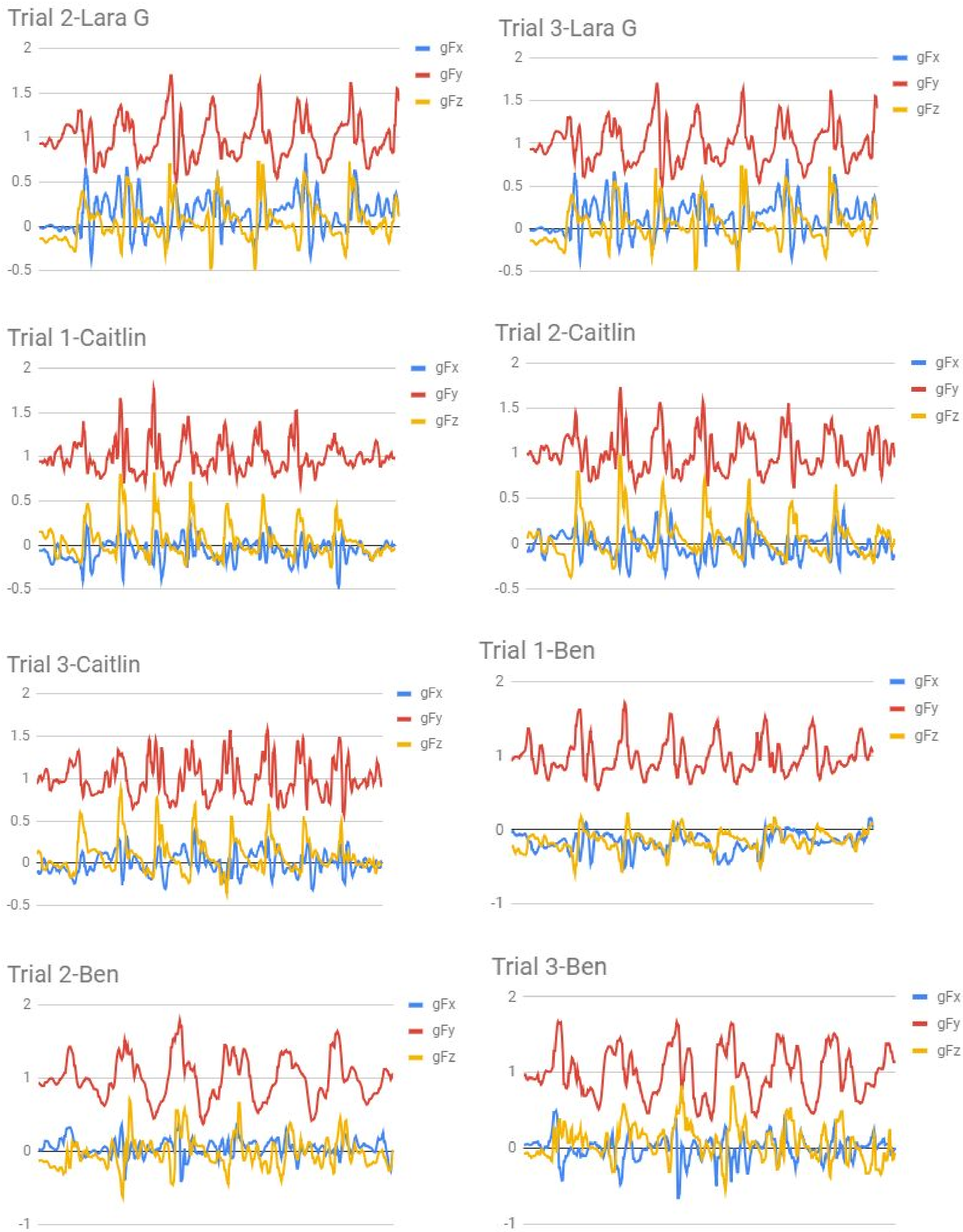


Figure 7: Graphs of all trials

To see original recorded data view Lara F's engineering notebook.