Team #501

BE 312 Spring 2021 Lab 2, Heart Lab

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Abstract

In this lab, we measured blood pressure and heart rate using both a stethoscope and an ECG. Two computers were used, one measuring blood pressure and lead I ECG data while the other collected lead II and lead III data. To begin with, we used a tape measure to determine the subject's height and travel distance. Then, we attached the electrodes to create the three leads for the ECG. During the experiment, we measured blood pressure while the patient was lying on the floor, then sitting in a chair, and finally after exercising for 5 minutes. Blood pressure was measured by tightening the blood pressure cuff until there is no sound with the stethoscope, then slowly loosening the cuff while listening for the systolic and diastolic Korotkoff noises. The ECG data was automatically recorded by the computer. After the experiment, we used the BSL Pro to analyze the data. We determined heart rate, and blood pressure based on our data. Then we measured the amplitudes and time duration of the P and T waves as well as the QRS complex. Next, we synchronized the completed ECG data and measured the lead voltages to create a vectorcardiogram. Finally, we used the vectorcardiogram to plot the Mean Electrical Axis. Our data showed no significant difference between using sound and the ECG for measuring heart rate, but there was a significant difference between using the marker and the transducer for determining blood pressure.

Questions

Sound vs ECG Data

1. How would you expect the speed of blood traveling through the arm to depend on the conditions we tested (seated, supine, and post-exercise)?

We would expect the blood to travel through the arm the fastest post-exercise. Our muscles need more oxygen after exercising, which causes our cardiac output to significantly increase. Since the muscles need more oxygen, this causes our heart to pump at a much faster rate and increases the blood flow throughout our bodies. Since our subject was standing after exercising, gravity assisted how the blood flowed through his arm. When standing, gravity causes the blood to flow down your body at a much faster rate.

When our subject was sitting, gravity was also assisting due to the test subject still having his heart at a more medial, proximal position than his brachial artery (meaning the gravity helped pull the blood from a higher level, the heart, to the brachial artery which is a at a distal, more lateral position). After the student exercised he was most likely warm from exercising and his heart was racing, which caused his blood vessels to dilate and allow for more rapid blood flow throughout his body. While the subject was in a supine position and sitting down the vessels remained in their normal state, meaning they did not dilate to allow for a larger blood flow. When the subject was in a supine position, the blood flow was slightly slower due to gravity not working in the body's favor. Since the body is in a horizontal position, only the pumping of the heart is causing the blood to flow throughout the body. The speed of blood flow was the greatest post-exercise, and then decreased as the subject was seated, and the slowest blood flow speed was when the subject was in a supine position.

2. Estimate the speed of blood traveling to the arm for each condition. Does this match your expectation from the previous question?

From the table shown below, it can be seen that post-exercise agrees with our expectation from above, that it will have the largest average pulse speed. It was expected that supine would have the slowest average pulse speed while post-exercise would have the fastest. According to our data, the supine position had a much faster average pulse speed than the seated position. This could be due to the fact that supine was our first trial, meaning it was more prone to human error. Some possible human errors are that the wires may have been loose/not connected well or the subject wasn't entirely still, which improved as the trials progressed.

To calculate the average pulse speed (mm/s), we used the average distance traveled, 457mm, and divide that by the delay ECG to sound. Since supine and seated had two trials each, we needed to take the average of the delay ECG to sound. Post-exercise had the fastest average pulse speed, while seated had the slowest average pulse speed.

Table 1: The average pulse speed vs. supine, seated, and post-exercise

Position	Supine	Seated	Post-Exercise
Delay ECG to Sound	0.223	0.253	0.192

[s]			
Average Pulse Speed [mm/s]	2050.36	1809.75	2380.21

3. Is there a significant difference between measuring the heart rate using sound and the ECG signal? If so, which do you feel is more accurate? Explain your reasoning.

When measuring the heart rate using sound, our data was slightly larger than that of the ECG data (although the two measurements produced very similar results). For example, our exercise trial produced an average of 118.874 BPM for sound and 118.036 for ECG, and our seated trial two produced an average of 77.512 BPM for sound and 77.174 for ECG. Using Excel, we calculated the average and standard deviation for each section. The supine and seated sections both have 10 trials whereas the exercise has only 5 trials. We used these to calculate a 95% confidence interval of the true averages.

Sound based Seated Heart Rate
$95\%\ C.I.\ =\ 72.37 \pm 1.96(5.62/sqrt(10))$
$95\%\ C.I.\ is\ 72.37 \pm 3.48$
$95\%\ C.I.\ range\ is\ from\ 68.89\ to\ 75.85$

Sound based Supine Heart Rate
$95\%\ C.I.\ =\ 64.41 \pm 1.96(7.51/sqrt(10))$
$95\%\ C.I.\ is\ 64.41 \pm 4.65$
$95\%\ C.I.\ range\ is\ from\ 59.75\ to\ 69.06$

Sound based Exercise Heart Rate
$95\%\ C.I.\ =\ 118.87 \pm 1.96(1.55/sqrt(5))$
$95\%\ C.I.\ is\ 118.87 \pm 1.36$
$95\%\ C.I.\ range\ is\ from\ 117.52\ to\ 120.23$

ECG based Seated Heart Rate
$95\%\ C.I.\ =\ 72.33 \pm 1.96(5.35/sqrt(10))$
$95\%\ C.I.\ is\ 72.37 \pm 3.32$
$95\%\ C.I.\ range\ is\ from\ 69.01\ to\ 75.65$

ECG based Supine Heart Rate
$95\%\ C.I.\ =\ 63.96 \pm 1.96(7.21/sqrt(10))$
$95\%\ C.I.\ is\ 63.96 \pm 4.47$
$95\%\ C.I.\ range\ is\ from\ 59.49\ to\ 68.43$

ECG based Exercise Heart Rate
$95\%\ C.I.\ =\ 118.04 \pm 1.96(1.60/sqrt(5))$
$95\%\ C.I.\ is\ 118.04 \pm 1.40$
$95\%\ C.I.\ range\ is\ from\ 116.64\ to\ 119.44$

Based on our confidence intervals, there is not a significant difference between measuring the heart rate using sound and the ECG signal. The confidence intervals for each section of the experiment were very similar when comparing sound based and ECG heart rates.

Although there was no significant difference between methods, we feel the ECG signal is more accurate than using sound to measure the heart rate. When finding the heart rate by sound a stethoscope is used, meaning there is room for human error, and we are only given the heart rate. ECG's measure the electrical activity of the heart by attaching electrodes/wire to the body, basically we are turning the body into a giant circuit. ECG records the electrical signal from a subject's heart and then provides a chart which typically shows heart rate and PR-QRS-T waves. The waves allow medical professionals to see if someone's heart is working properly (meaning they have a sinus rhythm and their heart rate is normal), if someone's heart is beating too fast or too slow, if they have a heart block, or if they need medical attention as soon as possible. A heart rate only gives us a portion of the story while an ECG provides a more holistic approach. A subject could have a fast heart rate when taken by a stethoscope/manually, but their ECG could reveal that they are about to have a heart attack; ECG's are showing us a more holistic picture of someone's heart and how it's working, which is more accurate. Additionally, ECG measurements are not subject to the same level of human error present when simply listening to sound via stethoscope.

BP Data

4. Is there a significant difference between measuring the blood pressure using the transducer signal or the recorder's ear (marker)? If so, which do you feel is more accurate? Explain your reasoning.

The transducer signal should be more accurate than the recorder's ear. The transducer is a machine that is supposed to identify when the pressure is changing from systolic to diastolic, while the recorder's ear is subject to many errors. First, the recorder may not be able to hear the blood pressure well due to a quiet beat or a loud room. Secondly, the recorder has to yell out when they hear a signal and the person running the computer has to respond to that and mark the change on the computer; this leaves plenty of room for error because there can be a large gap of time between the recorder hearing the switch from systolic to diastolic and when the person running the computer actually marks the change.

Although we expected the transducer to have more accurate readings, our data proved otherwise. Our marker data gave us accurate readings while our transducer did not. This can be seen in the seated data which stated the subject had a systolic pressure of 188mmHG, which is abnormally high. A typical systolic blood pressure is 100-119 mmHg, which we would expect the supine position to give a systolic reading around the lower threshold, and the seated to give a reading around the middle to upper threshold. A typical diastolic blood pressure is 60-79 mmHg, which we would expect the supine position to give a diastolic reading around the lower threshold, and the seated to give a reading around the middle to upper threshold. Post-exercise would have a much higher reading for systolic and diastolic since the cardiac output is much higher, meaning its normal to have a high blood pressure after working out.

We used Excel to find the average and standard deviations of the marker systolic and diastolic pressures, as well as the transducer systolic and diastolic pressures. Since we are checking for a difference between marker and transducer data, we combined seated, supine, and exercise into one data set, which gives us 5 trials. We used this to calculate 95% confidence intervals of the true averages.

Marker based Systolic Blood Pressure
$95\%\ C.I.\ = 108.00 \pm 1.96(8.77/sqrt(5))$
$95\%\ C.I.\ is\ 108.00 \pm 7.69$
$95\%\ C.I.\ range\ is\ from\ 100.32\ to\ 115.69$

Marker based Diastolic Blood Pressure
$95\%\ C.I.\ = 60.67 \pm 1.96(6.85/sqrt(5))$
$95\%\ C.I.\ is\ 60.67 \pm 6.01$
$95\%\ C.I.\ range\ is\ from\ 54.67\ to\ 66.68$

Transducer based Systolic Blood Pressure
$95\%\ C.I.\ = 160.18 \pm 1.96(26.54/sqrt(5))$
$95\%\ C.I.\ is\ 160.18 \pm 23.26$
$95\%\ C.I.\ range\ is\ from\ 136.92\ to\ 183.45$

Transducer based Diastolic Blood Pressure
$95\%\ C.I.\ = 50.00 \pm 1.96(10.20/sqrt(5))$
$95\%\ C.I.\ is\ 50.00 \pm 8.94$
$95\%\ C.I.\ range\ is\ from\ 41.05\ to\ 58.94$

Based on our confidence intervals, there is a significant difference between maker and transducer systolic pressures. The systolic pressure confidence intervals don't overlap at all. The diastolic pressure confidence intervals overlap from 54.67 to 58.94 mm Hg. This suggests that the difference between marker and transducer data for just the diastolic pressure may not be significant.

5. How would you expect systolic and diastolic pressure to vary based on condition?

Blood pressure tends to increase as a subject goes from supine to seated to standing/post-exercise, which is also known as orthostatics. When a person changes position (supine to sitting or sitting to standing) their cardiovascular system responds by making the cardiac output larger/the heart beat faster, which causes an increase in the blood pressure and heart rate. This also causes the systolic and diastolic pressures to increase as well, because the muscles and organs still need blood and oxygen. Since the overall blood pressure increases as the subjects position changes from supine to seated to standing/post-exercise, we would expect the systolic and diastolic blood pressures to also increase. The body's demand for blood and oxygen must be met by the cardiovascular system, meaning there is a demand for a higher cardiac output. Since blood pressure is composed of systolic and diastolic pressures, it's assumed they increase because they are the blood pressure. If the subject was going from standing/post-exercise to seated to the supine position, we would expect the overall blood pressure to decrease, meaning the systolic and diastolic pressures will also decrease.

6. Estimate of the average systolic and diastolic pressures under the three conditions. Present your findings in a well-structured table. Explain any assumptions of reasoning you made when developing this table. Does this match your expectation from the previous question?

Table 2: Average systolic & diastolic pressures measured for supine, seated, and post-exercise conditions via marker & transducer

	Supine		Seated		Post-Exercise	
	Marker	Transducer	Marker	Transducer	Marker	Transducer
Avg. systolic pressure [mm Hg]	103.037	145.3	108.2775	188.617	117.393	145.238
Avg. diastolic pressure [mm Hg]	66.0765	48.7745	60.495	58.108	50.231	36.216

When estimating the average systolic and diastolic pressures under the three conditions it was assumed that, due to the significant difference between measuring via transducer and marker, the average pressures measured through each method would also differ. Therefore, averages were calculated separately based on the measuring method. It was also assumed that these three conditions, supine, seated, and post-exercise, were the only variables impacting changes in systolic/diastolic pressure.

Our results do not match our expectations stated in the prior question, we expected the transducer to be more accurate but that was incorrect. Our transducer was giving abnormally high values that exceeded 160mmHg, although the blood pressure cuff never exceeded 160mmHg. Although we expected the transducer data to be more accurate, the marker data was proven to be more accurate due to the systolic and diastolic values. As stated previously, a typical systolic blood pressure is 100-119mmHg, which we would expect the supine position to give a systolic reading around the lower threshold, and the seated to give a reading around the middle to upper threshold. A typical diastolic blood pressure is 60-79mmHg, which we would expect the supine position to give a diastolic reading around the lower threshold, and the seated to give a reading around the middle to upper threshold. Post-exercise would have a much higher reading for systolic and diastolic since the cardiac output is much higher, meaning its normal to have a high blood pressure after working out. Our transducer data does not agree with our expectations above, that the systolic and diastolic readings would increase as the subject went from supine to seated to post exercise, and that the systolic and diastolic readings would decrease as the subject went from post exercise to seated to supine. Our systolic data for the markers agrees with our previously stated expectation, but our diastolic data disagrees with the expectation. Our diastolic data may be disagreeing with our expectation due to human error, such as the input of the markers were delayed or the recorder not being able to hear the switch to diastolic well.

ECG Waves Data

7. Create a well-formatted figure of the one seated ECG cycle. Indicate the various waves and corresponding times and amplitudes along with the systole and diastole segments.

Figure 1 is made using data from the first ECG cycle of the seated trial.

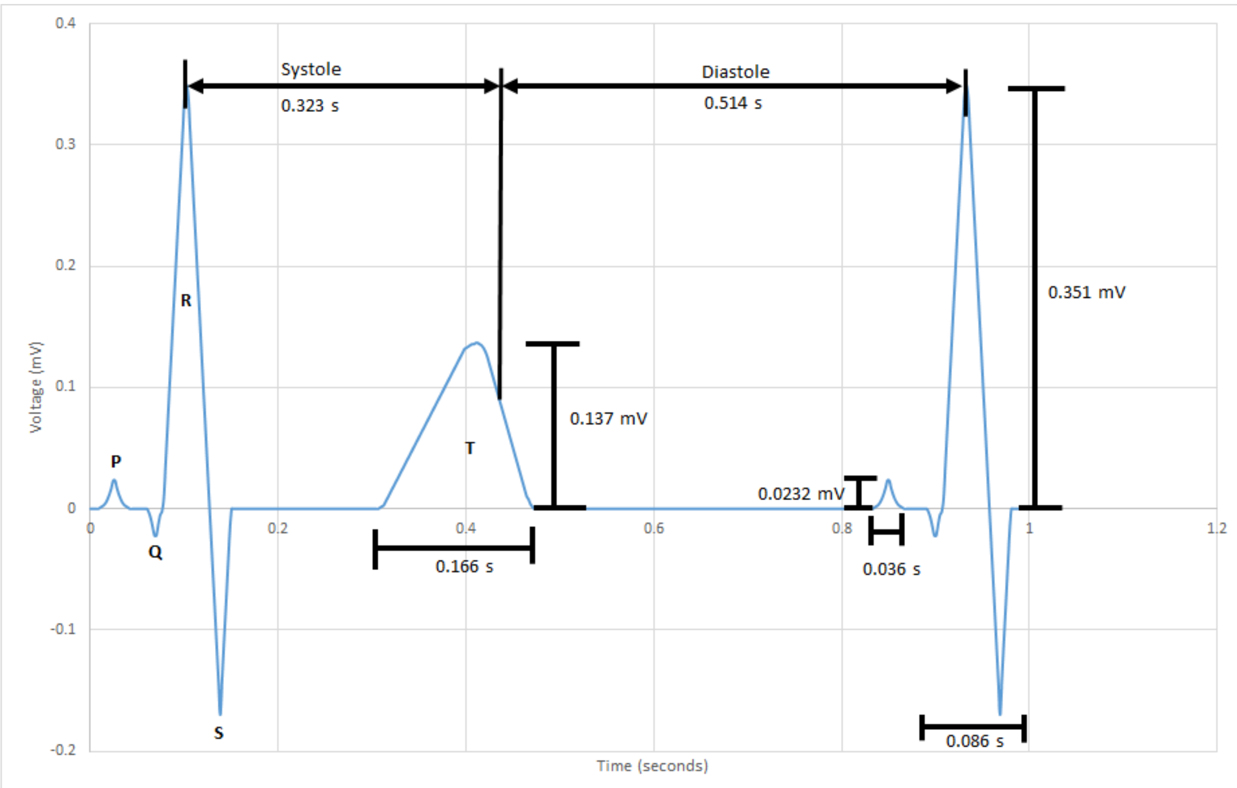


Figure 1: Labeled ECG Cycle
This figure shows the amplitudes in mV and time duration in seconds for the P and T waves as well as the QRS complex. Additionally, the systole and diastole time periods are labeled.

Einthoven's Law

8. What is Einthoven's law? Using circuit analysis, prove Einthoven's law. This can be by hand or with equations in Word.

Einthoven's law states that when an electrocardiogram is taken with three leads on three separate limbs, the potential in leads one and three at any given time can be used to extrapolate the potential in lead two. Therefore, the calculation for the potential in lead two is simply the sum potentials of leads one and three. Einthoven's law is therefore formally defined as:

$V_I + V_{III} = V_{II}$ $\quad Expanded: (V_{LA} - V_{RA}) + (V_{LL} - V_{LA}) = (V_{LL} - V_{RA})$

The expanded version of this formula shows how the voltages of the left and right arms, and the left leg, all balance each other. Einthoven's Triangle is a physical representation of this law. Because the triangle is equilateral, we can relate the formula for lead potential to the geometry of the triangle. Let Einthoven's triangle be defined as shown below:

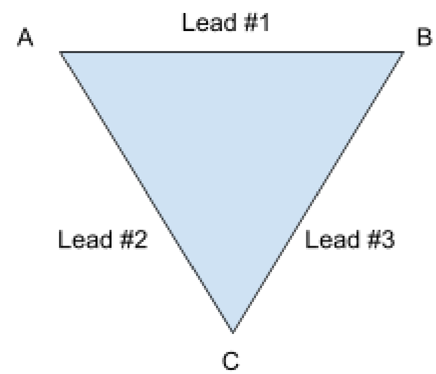


Figure 2
Diagram of Einthoven's Triangle

Let lead 1 be defined as L1, lead 2 as L2, and lead 3 as L3. We can apply the law of cosines to this diagram as follows:

$Law\ of\ Cosines: a^2 = b^2 + c^2 - 2bc * cos(A)$

For Lead 1 (AB): $(AB)^2 = L1^2 + L2^2 - L1 * L2$

For Lead 2 (AC): $(AC) = L1^2 + L3^2 - L1 * L3$

For Lead 3 (BC): $(BC)^2 = L2^2 + L3^2 + L2 * L3$

Substitute Einthoven's Law, $L1 - L3 = L2$, into the BC and AC formulas to show equivalence.

$$(BC)^2 = L2^2 + (L1 - L2)^2 + L2(L1 - L2) = L1^2 + L2^2 - L1 * L2 = (AB)^2$$

$$(AC)^2 = L1 + (L1 - L2)^2 - L1(L1 - L2) = L1^2 + L2^2 - L1 * L2 = (AB)^2$$

Therefore, $(AB)^2 = (BC)^2 = (AC)^2$ confirms that Einthoven's triangle is equilateral. This fact proves that Einthoven's law is valid, as the sides of an equilateral triangle with angular position and magnitude taken into account balance out.

9. Is Einthoven's law verified during for all of the seated segment? If so present data to back your claim. If not, show how it is violated and give a possible explanation for this violation.

Einthoven's law states that voltage of lead II will equal the sum of voltages between lead I and III. With this in mind, the voltage summation of lead I and lead III subtracted by voltage of lead II should ideally equal zero. To verify Einthoven's law for the seated portion of this lab, data collected from leads I, II, and III were used to plot V1+V3-V2 for the entire segment duration.

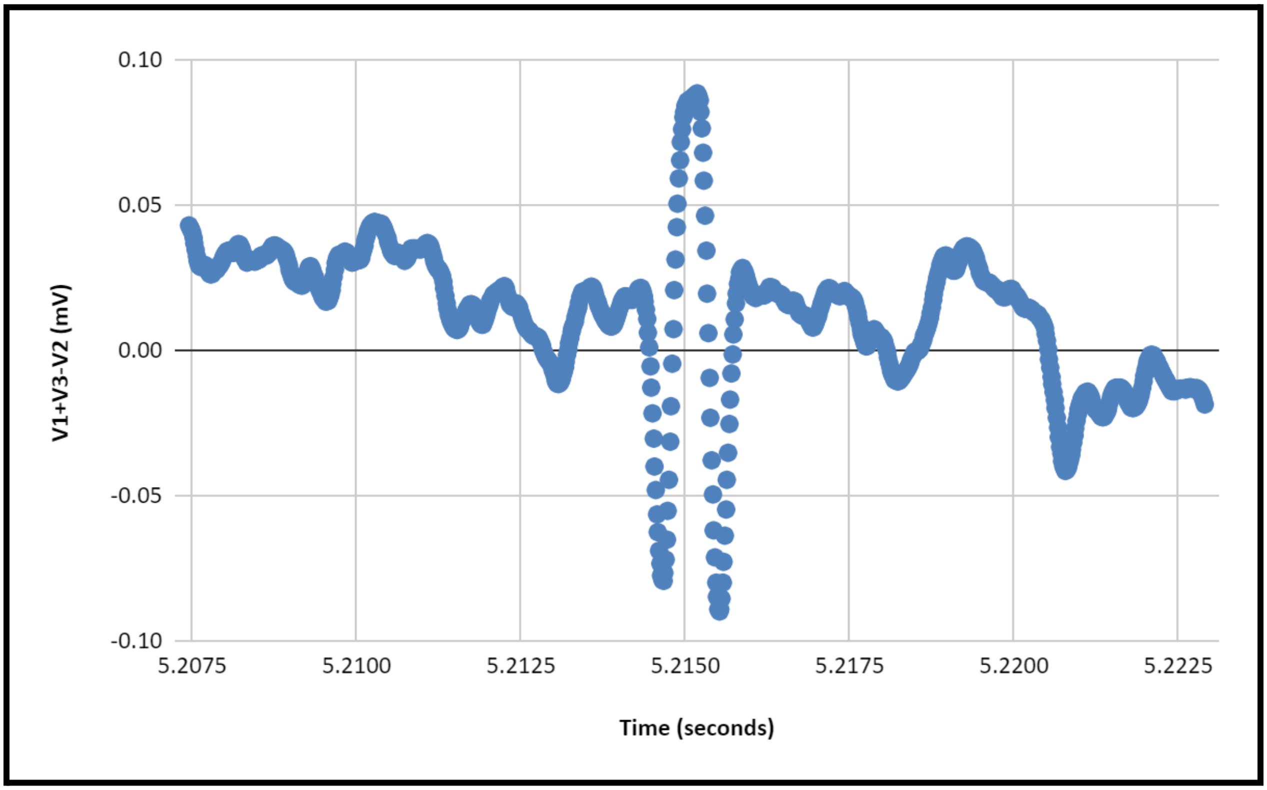


Figure 3: Plot of V1+V3-V2 of the seated data

Using the =AVERAGE() function within excel, the average value for V1+V3-V2 for the segment was determined to be 0.0125. The standard deviation within the V1+V3-V2 data was calculated to be 0.0254 using the =STDEV() function in excel. Using this data a 95% confidence interval was calculated.

$95\%\ C.I.\ =\ 0.0125 \pm 1.96(0.0254/sqrt(2784))$
$95\%\ C.I.\ is\ 0.0125 \pm 0.000943$
$95\%\ C.I.\ range\ is\ from\ 0.01157\ to\ 0.0134$

With the confidence interval being close to zero, Einthoven's Law can be verified. Ideally all the values for VI+V3-V2 throughout the section should equal zero, but human error in the placement of the electrodes, environmental noise, and movement can skew the data.

The graph has some background noise which accounts for all the waves that vary from 0/the x-axis. Around 5.2150 second, the graph experienced a large S wave dip, which could have intensified due to noise. The S wave is normally a negative wave that dips below the x-axis, but it may have dipped lower than normal due to human errors such as background noise. There is also the possibility of the test subject having an abnormal ECG rhythm during the seated portion of testing, but human error (such as noise) is more likely.

This verifies Einthoven's Law for the seated portion of the experimental results.

10. Is Einthoven's law verified during all of the post-exercises segment? If so present data to back your claim. If not, show how it is violated and give a possible explanation for this violation.

Einthoven's law is formally defined as:
$V_I + V_{III} = V_{II}$ $\quad Expanded: (V_{LA} - V_{RA}) + (V_{LL} - V_{LA}) = (V_{LL} - V_{RA})$, meaning the voltage summation of lead I and III subtracted by the voltage of lead II, should ideally equal zero. To verify Einthoven's law for the post-exercise portion of the lab, data collected from leads I, II, and III were used to plot V1+V3-V2 for the entire segment duration, as seen in question 9.

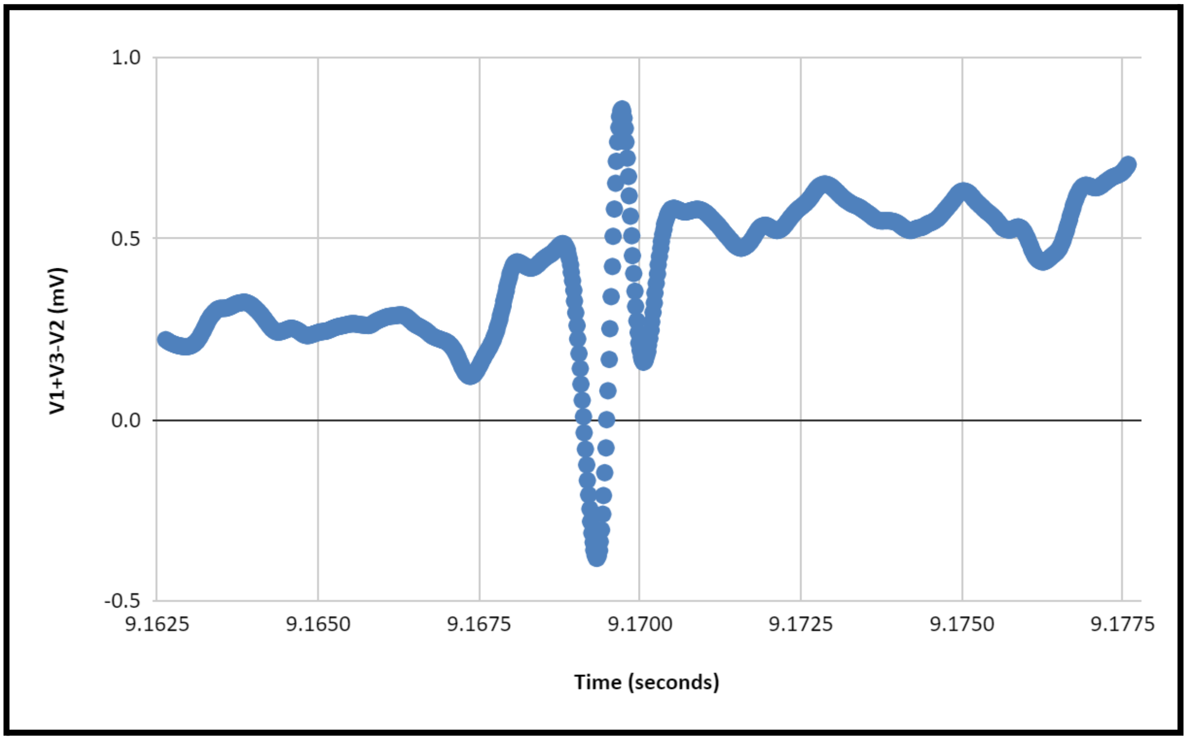


Figure 4: Post-Exercises Lead Voltages

We first used the =AVERAGE() Excel function to calculate an average of 0.413 for V1+V3-V2. We then used the =STDEV() Excel function to calculate the standard deviation of V1+V3-V2, which was 0.195. We finally calculated the error by using the 95% confidence intervals of the data:

$95\%\ C.I. \ = \ 0.413 \pm 1.96(0.195/sqrt(2694))$
$95\%\ C.I.\ is\ 0.413 \pm 0.00736$
$95\%\ C.I.\ range\ is\ from\ 0.406\ to\ 0.420$

The graph has some background noise which accounts for all the waves that vary from 0/the x-axis. Around 9.1700 we can see a normal ECG wave, which is surrounded by some background noise.

Einthoven's law is not verified for the post exercise data due to the background noise slowly increasing as the plot continues. The background noise begins around a V1+V3-V2 level of ~0.300mV but slowly rises to values about ~0.600mV. We would expect the background noise increase due to human error, such as additional noise the machines picked up, incorrect electrode placements, or subject movement.This is a significant difference because we would expect the values to be much closer to zero if Einthoven's law was verified, meanwhile our 95% confidence interval range is from 0.406 to 0.420.

MEA Plots

11. Make a table that presents the R-wave and QRS data used to make the MEA plots.

Table 3**:** R-Wave data used to make MEA plots for seated, supine, and post-exercise conditions

R-Wave [mV]			
Lead	Seated	Supine	Post Exercise
Lead 1	.100	.110	.390
Lead 2	.660	.710	1.14
Lead 3	.590	1.14	.230

Table 4**:** QRS data used to make MEA plots for seated, supine, and post-exercise conditions

QRS [mV]			
Lead	Seated	Supine	Post Exercise
Lead 1	.350	.180	.730
Lead 2	1.00	.100	1.80
Lead 3	.750	.750	.311

12. Derive equations for the EAV magnitude and angle based on Lead II and III. This can be by hand or with equations in Word.

The equations for EAVx and EAVy are given in the lab instructions according to leads one and three as follows:

$$EAV_X = V_1$$

$$EAV_Y = -0.5774(2V_3 + V_1)$$

We can augment these given formulas to follow leads two and three instead of leads one and three as provided. This can be done by transforming Einthoven's Law to be equal to V1, and substituting into the equations above. The result of this derivation is as follows:

$$V_1 = V_2 - V_3$$

$$EAV_X = V_2 - V_3$$

$$EAV_Y = -0.5774(2V_3 + (V_2 - V_3)) = -0.5774(V_3 + V_2)$$

$$|EAV| = \sqrt{EAV_X^2 + EAV_Y^2} = \sqrt{(V_2 - V_3)^2 + (-.5774(V_3 + V_2))^2} = \sqrt{1.333V_2^2 - 1.333V_2V_3 + 1.333V_3^2}$$

We can derive a formula for the angles associated with leads two and three by calculating the overall magnitude of the combined components

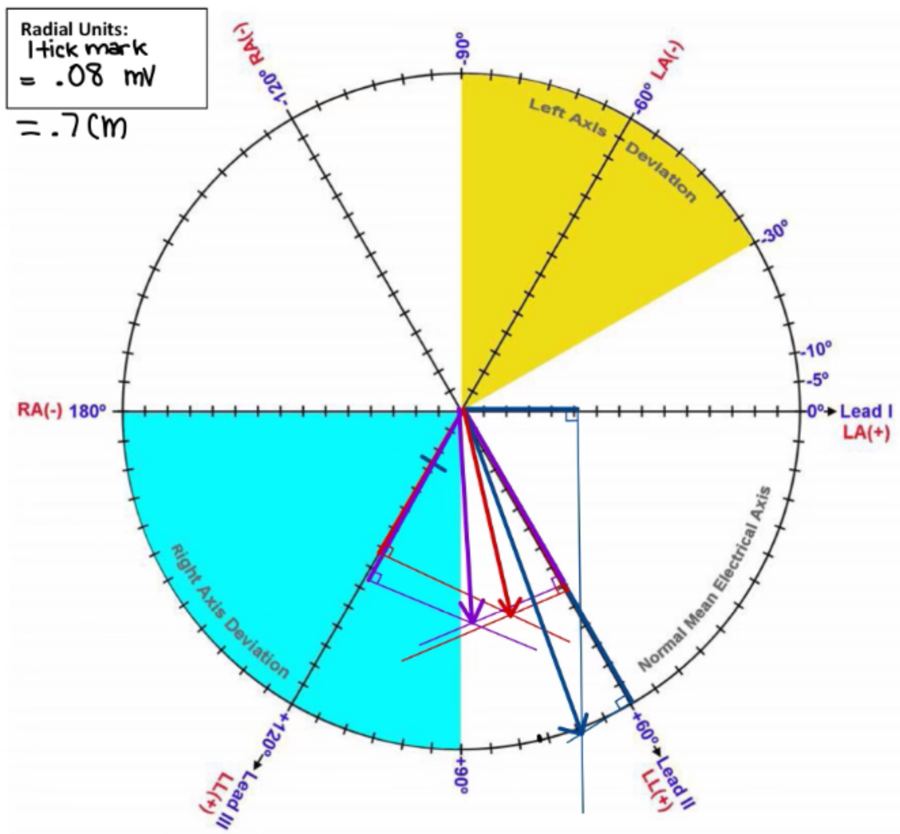
$$\theta = tan^{-1}(EAV_y/EAV_x)$$

$$\theta = tan^{-1}((-0.5774(V_3 + V_2))/(V_2 - V_3))$$

13. Make the MEA plot listed below including measuring the MEA angle and magnitude (instructions in procedures). ***These plots must be done by hand, not via computer****:*

Name:		Group#	0501A	Subject #	1

	Method (R wave or QRS) →	R-Wave
Condition	**Magnitude [mV]**	**Angle [deg]**
Seated	.77	87°
Supine	.75	76°
Post Exercise	1.2	69°

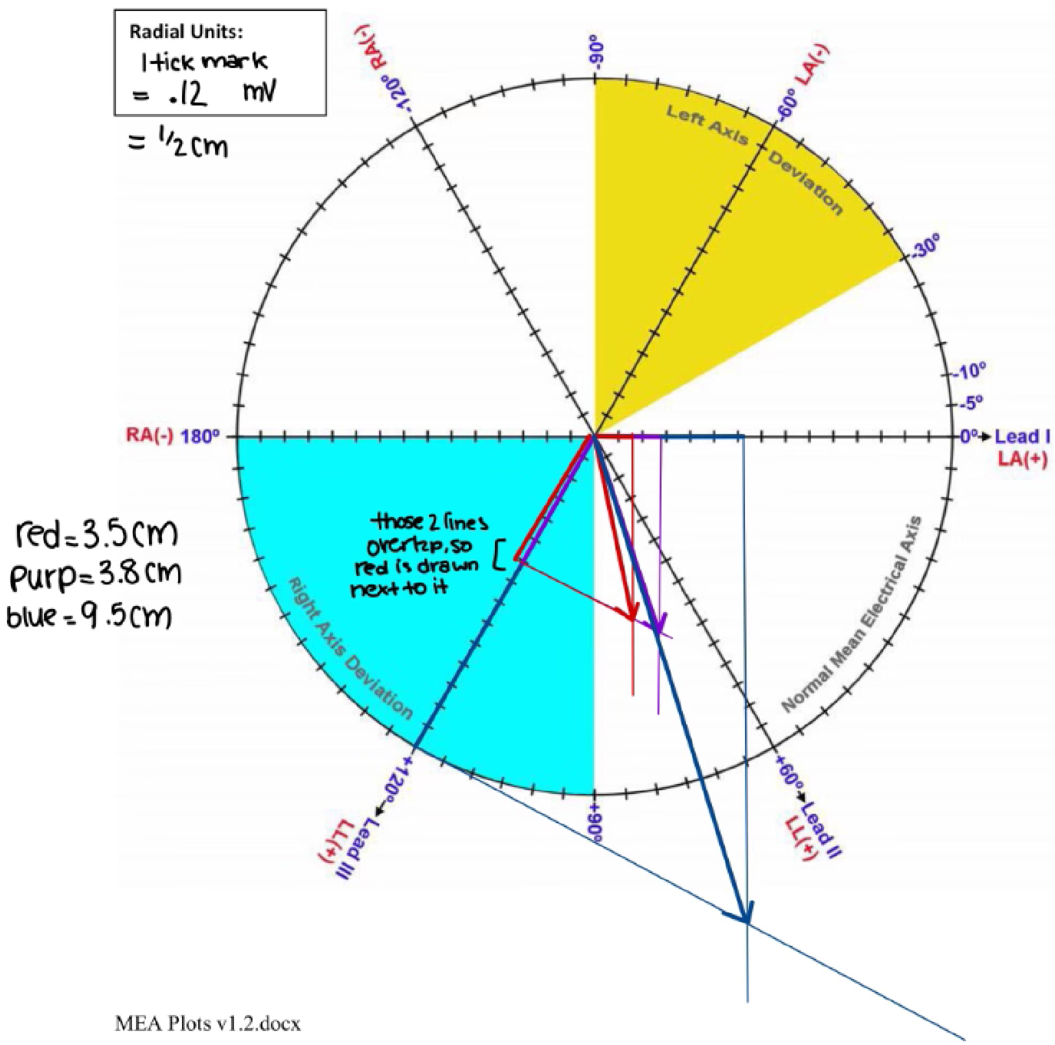


MEA Plots v1.2.docx

Figure 3: Subject 1, MEA based on R wave for all 3 conditions

Name:		Group#	0501A	Subject #	1

	Method (R wave or QRS) →	QRS
Condition	Magnitude [mV]	Angle [deg]
Seated	.91	77°
Supine	.84	72°
Post Exercise	2.12	73°



MEA Plots v1.2.docx

Figure 4: Subject 1, MEA based on QRS for all 3 conditions

Vectorcardiograms

14. Using the same cycles used to make the MEA plots, present the vectorcardiogram for each condition in well-formatted figures (one for each condition). Screenshots will not be accepted. On one of the figures highlight the significant features of the vectorcardiogram that correspond to the activity in the heart. Use whichever condition shows the relevant features of the clearest.

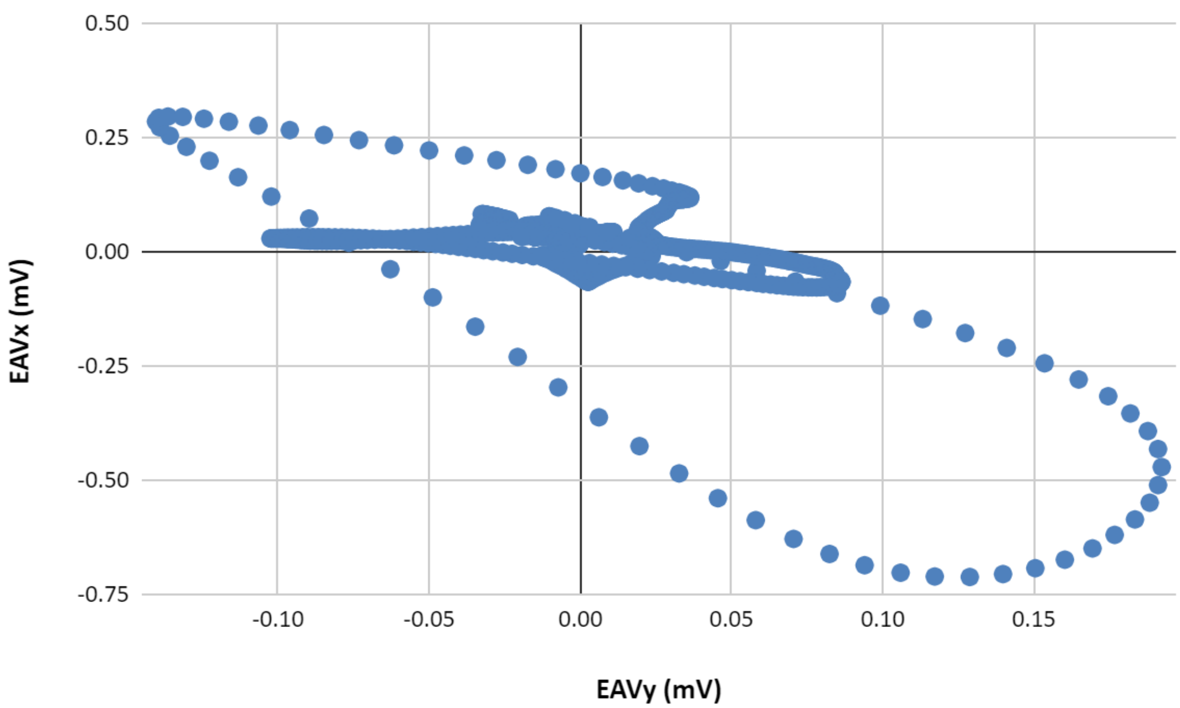


Figure 5

Vectorcardiogram for Supine Heart Activity

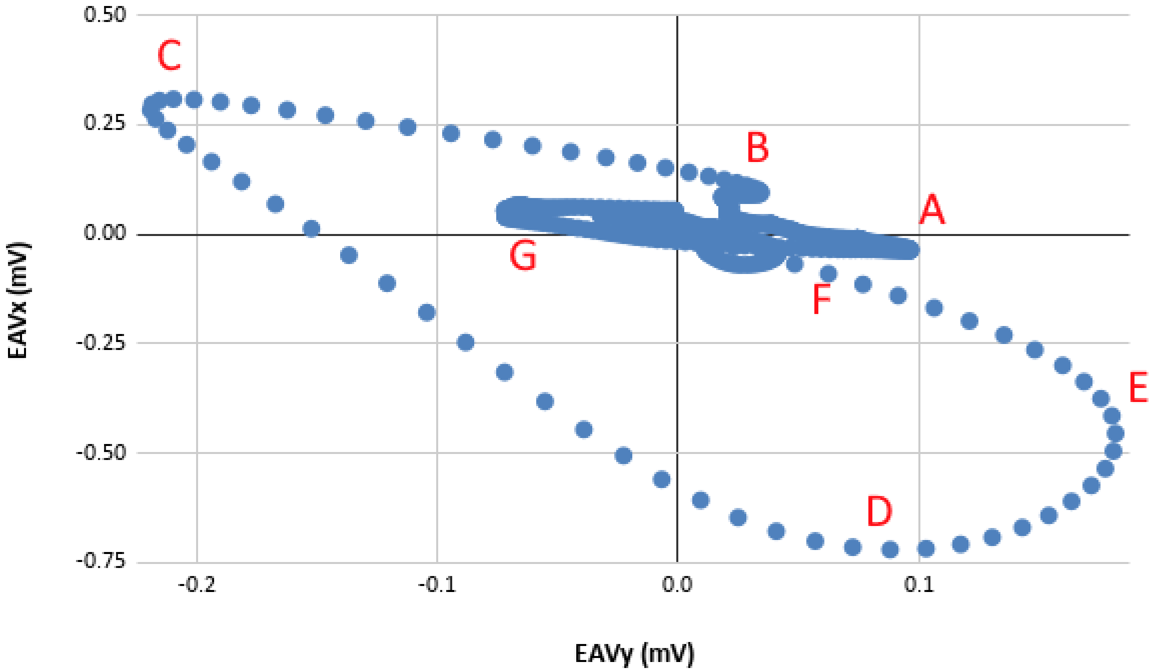


Figure 6
Vectorcardiogram for Seated Heart Activity
A. *Atrial Depolarization,* ***B.*** *Septal Depolarization,* ***C.*** *Apical Depolarization,* ***D.*** *Depolarization of Left Ventricle,* ***E.*** *Late Depolarization of Left Ventricle,* ***F.*** *Full Depolarization,* ***G.*** *Ventricular Repolarization*

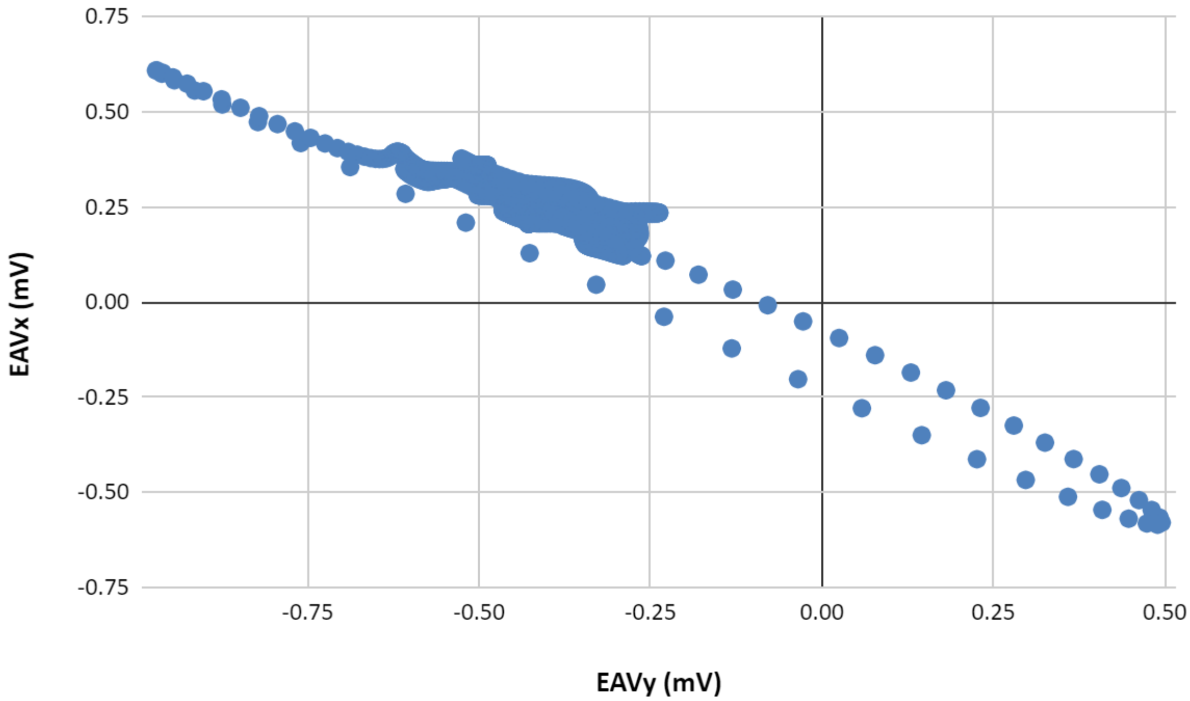


Figure 7
Vectorcardiogram for Post-exercise Heart Activity

15. How does the curve change between each condition? What could explain these changes?

The vectorcardiodiagram for the supine and seated positions show similar curves, although there are small variances in the different angles and magnitudes of the EAV values. The vectorcardiogram for the post exercise activity is very abnormal when compared to supine and seated, most likely due to incorrect data.

In general, the marker data points were along the lines of accurate results while the transducer data points were very off. The transducers value of delta for post exercise does not follow Einthoven's law, which would account for why the vectorcardiogram is very narrow/elongated, and why the large mass of data points isn't near the origin, unlike the diagrams for the supine and seated positions.

Although the post exercise data does not follow Einthoven's law, the data for the supine and seated positions do follow Einthoven's law. Since both the supine and seated data follow Einthoven's law, this explains why both vectorcardiodiagrams have very similar curves, while the post exercise vectorcardiogram looks very different due to not following Einthoven's law since the data is inaccurate.

The curves of the supine and seated data could be different due to the lower heart rate of the supine experiment, which could explain the sharper curves and longer central mass of data points, which may be reflective of a lower resting heart rate.

Comparisons

You will now compare the various ways to derive the MEA. In question 11 you measured value based on R-wave and QRS data. Then using the data in Questions 9 and 10, and the relevant equations, you can find a calculated value for R-wave and QRS data. Finally, you can find the "true MEA" by calculating the EAV magnitude and angle for the whole cycle, and finding when the EAV reaches its maximum value.

16. Present the two measured, two calculated, and true MEA for each state in a well-formatted table.

Table 5: Measured & calculated MEA values based on the R-Wave, along with the true MEA value

	Measured (R-Wave)		Calculated (R-Wave)		True MEA	
	Magnitude	Angle	Magnitude	Angle	Magnitude	Angle
Supine	.75	76	.75	79.94	.72	79.75
Seated	.77	87	.73	84.18	.72	83.01
Post-Exercise	1.2	69	1.33	41.16	1.15	32.05

Table 6: Measured & calculated MEA values based on the QRS, along with the true MEA value

	Measured (QRS)		Calculated (QRS)		True MEA	
	Magnitude	Angle	Magnitude	Angle	Magnitude	Angle
Supine	.84	72	.91	37	.72	79.75
Seated	.91	77	1.08	74.05	.72	83.01
Post-Exercise	2.12	73	2.20	39.50	1.15	41.16

17. Do the various values for the MEA magnitude and angle agree? If not explain why. Support your explanation with a graphic if applicable.

The R-wave MEA values are in a much closer proximity to the other data points, in comparison to the QRS MEA values. The measured QRS values are much closer to the true QRS MEA values, while the calculated values varied slightly. The calculated R-wave values are much closer to the true R-wave MEA values, while the measured values varied.

The post exercise data had much larger values due to the data points being inaccurate; the transducer data gave higher/abnormal blood pressure data points, which has led to the larger difference in values. If the post exercise data wasnt giving abnormal values, we would expect the results to be more similar to the magnitudes and angles of the supine and seated positions.

BP Analysis

18. Using the combined data for your group (A or B), create a plot showing mean blood pressure (MBP) for seated experiment vs height. MBP = [2 × (DBP) + SBP]/3 where DBP = diastolic blood pressure, and SBP = systolic blood pressure. Determine if there is any correlation between the two. Explain your data, your plot, and your conclusion.

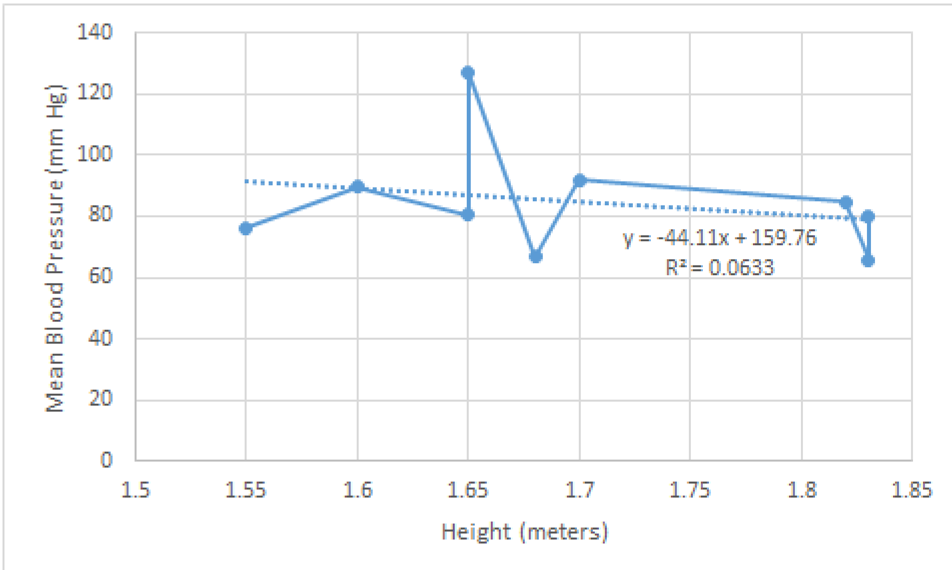


Figure 8: Marker Mean Blood Pressure vs Height
Mean blood pressure according to the marker data is plotted on the y-axis, while height is on the x-axis. The trendline is drawn and the equation shown on the graph.

This trendline might suggest a negative correlation between mean blood pressure and height. However, creating the same plot using the transducer means blood pressure gives a different result, as shown in Figure 9.

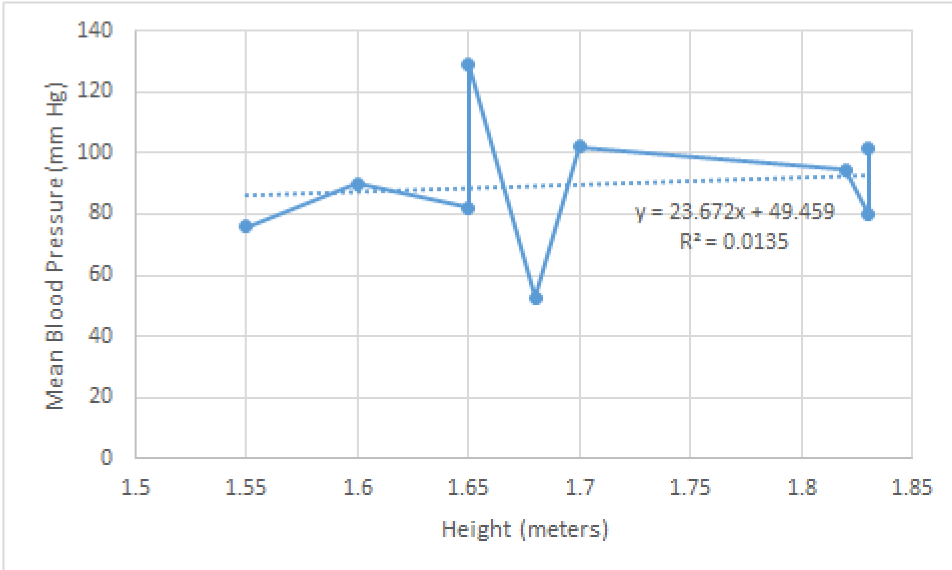


Figure 9: Transducer Mean Blood Pressure vs Height
Mean blood pressure according to the transducer data is plotted on the y-axis, while height is on the x-axis. The trendline is drawn and the equation shown on the graph.

Using the mean blood pressure based on the transducer gives us a trendline that suggests a positive correlation. Since these trendlines contradict each other, there does not appear to be any correlation between mean blood pressure and height.

Extra Credit

19. What is the variability in heart rate in seated and supine conditions? Use all of the data in these conditions to get a good answer (hint: use the find peak function)

Using the confidence intervals from Question 3, we can look for outliers in our data. Our sound based heart rate values were used to calculate the standard deviations provided below.

Sound based Seated Heart Rate

$95\%\ C.I. = 72.37 \pm 1.96(5.62/sqrt(10))$

$95\%\ C.I.\ is\ 72.37 \pm 3.48$

$95\%\ C.I.\ range\ is\ from\ 68.89\ to\ 75.85$

Sound based Supine Heart Rate

$95\%\ C.I. = 64.41 \pm 1.96(7.51/sqrt(10))$

$95\%\ C.I.\ is\ 64.41 \pm 4.65$

$95\%\ C.I.\ range\ is\ from\ 59.75\ to\ 69.06$

Based on these confidence intervals, 8 of the 10 measured heart rates in the seated section are outliers. This is largely because the first 5 heart rates are noticeably smaller than the second set of 5, which impacts the range of the confidence interval. This suggests a fair amount of variability in heart rate when seated.

Based on these confidence intervals, 4 of the 10 measured heart rates in the supine section are outliers. This suggests that there is less variability in heart rate when laying down than when sitting.