Postural Effects on an Individual's RSA (Respiratory Sinus Arrhythmia)

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***Abstract*— The research study investigated the relationship between posture and RSA values. Electrodes were placed on seven adult male participants aged 18-24 with no known breathing issues. Participants inhaled and exhaled at a constant rate for 2 minutes in 3 different bodily postures which included standing, sitting and lying down. The ECG signal was recorded at each posture generating the heart rate and breathing rate. The difference between heart rate when exhaling verses inhaling was compared. These results from the BioRadio were plotted as a function of time to calculate the RSA. A t-test was performed and average RSA values of 1.8763, 3.5437 and 4.0473 were obtained for supine, sitting and standing positions respectively. Despite these small RSA values, the results had further acknowledged the effect on RSA and that it was the most eminent in the standing position. For future prosperous studies, the role of bodily postures in overall heart health could be investigated to find solutions to heart diseases with a greater sample testing size to provide greater confidence levels within the results.**

***Index Terms*—Electrocardiography (ECG), Respiration Inductance Plethysmography (RIP), Respiratory Sinus Arrhythmia (RSA)**

I. Introduction

Factors associated with heart attacks have always been a prominent issue. In 2015, an estimated 17.7 million people across the globe died by a cardiovascular disease (e.g., heart attack, stroke, etc.) [1]. These individuals can be put on blood thinners, undergo angioplasty surgeries, be put on respirators or have heart transplants. However, these solutions do not address the issue of predicting when a heart attack may occur or how to deal with the situation as it arises. Furthermore, many of these solutions are invasive and put further pressure on the heart.

The objective of this study is to determine if an individual's posture can alter the effects of RSA. The results of this study can be used to determine which bodily postures can lead to an increased RSA effect. This knowledge can help those control their heart rate in times of need such as during a heart attack.

Looking at previous studies, ECG graphs have been used to calculate an individual's RSA; this includes analyzing their breathing and comparing it to their change in heart rate. Considering that ECG signals have a lot of data and noise, algorithms must be used to derive experimental values for the difference in heart rate during inhalation and exhalation at each posture. Each trial will conclude with different results unique to everyone, a T test must be employed to accurately test the viability of our data.

Our hypothesis is that the difference in ECG period from inhalation to exhalation will be highest in a standing posture and lowest in a supine posture. In other words, the effect of RSA will be greatest in standing posture and lowest in supine posture. In terms of bodily postures, standing up should place the greatest burden on the heart as opposed to sitting or lying down. Recall that the force due to gravity acts downwards. There would need to be an opposing gradient that must transport oxygen to elevated areas of the body, such as the brain. To create this opposing gradient, there would need to be a greater force that would have to originate from the heart. The heart can achieve this extra force and pressure through increasing the heart rate and therefore the RSA is expected to increase in a standing posture.

II. Methods

A. *Setup of Data Collection with ECG*

The study consisted of seven male adult students (ages 18-24) with no health problems that could affect their breathing patterns. The experiment consisted of several pieces of equipment to measure the participant's respiration and electrocardiogram which were all attached to the BioRadio. The BioRadio can measure an individual's ECG, breathing rate, and heart rate using data from the equipment attached; Figure 1 below provides a sample BioRadio used in the experiment.

Figure 1: BioRadio Equipment

Three electrodes were also attached to the participant: one on the right inner wrist, one on the left inner wrist, and another on the right knuckle. Additionally, a pulse oximeter was placed on the right index finger to measure heart rate/respiration inductance plethysmography (RIP) shown in Figure 2 below.

Figure 2: Electrodes and Pulse BioRadio Equipment

Electrical activity is measured across the heart using electrodes shown in Figure 2 to retrieve the heart rate. The Piezo Electric Respiratory Effort Belt was strapped around the participant's chest. Shown in Figure 3 the belt was specifically strapped around the upper thoracic cavity to measure the breathing rate and further enhance the accuracy of the results.

Figure 3: Piezo Electric Respiratory Effort Belt

The BioRadio was connected to a computer via Bluetooth to relay the signal graphically on the BioCapture software. After all the equipment was ready for testing, the participants were asked to breathe at a constant rate while standing upright with their arms on their sides for three minutes. After this posture was completed, patients were given a one-minute interval to prepare and regain constant breathing for another two-minute breathing test. The participant changed postures to a sitting position for a two-minute test followed by a 1-minute rest, concluding with one more test in a supine posture.

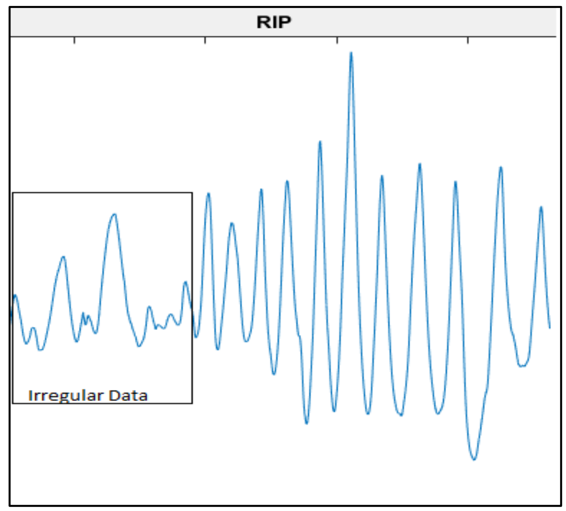
B. Processing Data with ECG

The BioCapture software recorded input values from the BioRadio creating graphical data to portray the breathing and heart rates. The data was then exported into raw comma-separated values (CSV) that can be used by Microsoft Excel. CSV raw data files displayed both ECG and RIP rates in terms of time in intervals of 0.002ms. The data was then imported into a MATLAB algorithm measuring the R-R intervals determining each individual RSA.

C. Statistical Data Analysis

Over the span of the three minutes that the data was gathered, only five breathing cycles are chosen. In other words, from an estimated total of 90,000 points gathered, approximately only 15,000 (5 consecutive breathing cycles) will be used. The specific data points were selected from readings that occurred around the second to third minute of the experiment to avoid any calibration error that may have been caused by the BioRadio. In addition, the chosen data was selected ensure that the individual's breathing was constant and smooth. After some research, it was proven that individual's breath differently when told that they are being tested – as they become more conscious. To encounter this problem, ending breathing data points were used to find the RSA. Along with it, irregular samples as shown in Figure 4 were discarded from the breathing cycle to obtain a better result.

Figure 4: Irregular data gathered in RIP



After the 5 consecutive breathing cycles that were going to be used were selected from the generated excel sheet, the data was then inserted into a "Complete Pan Tompkins Implementation ECG QRS Detector" by Hooman Sedghamiz [4]. Although the Pan Tompkins MATLAB code helps with calculating the QRS complex in an ECG signal, the BioRadio readings did not provide us with the exact readings that was required to use the Pan Thompkins code. To resolve this issue, with the help of "Example of Measuring Heart Rate from acquired ECG signals" [5], the group was able to successfully code a program that worked with the Pan Tompkins code to use the data provided by the BioRadio. Thus, the ECG breathing signals/values were obtained to find the RSA. The 5 consecutive breathing cycles were taken half a cycle each to obtain 5 different values for the rate of inhalation and another 5 values for the rate of exhalation. The average of the 5 values were respectively taken to determine the average rate of inhalation and exhalation.

Furthermore, a t test was conducted with an alpha value of +/- 5%. From the t-test, the p-value (in percent) will determine if the values gathered were rejected or not rejected using the values created from MATLAB. Values for p greater than alpha highlights that the null hypothesis was not rejected, indicating that the data has no significant differences. Whereas if p is less than alpha, the results will reject the null hypothesis indicating significant changes within the data. There will be a total of 3 comparisons that will be observed – sitting vs. supine, sitting vs. standing, and standing vs. supine.

III. Results

Individual RSA values computed in Figure 4 was calculated using the Pan Tompkins algorithm in MATLAB. The relationship between posture and RSA with males is shown in fig. 4. The average RSA values for lying is 1.8763 ms, sitting is 3.5437ms, and standing is 4.0473ms. Table 1 below shows p-values calculated from the t-test comparing lying and sitting posture to be 13.43%, sitting and standing to be 64.31%, and lying and standing to be 3.1%.

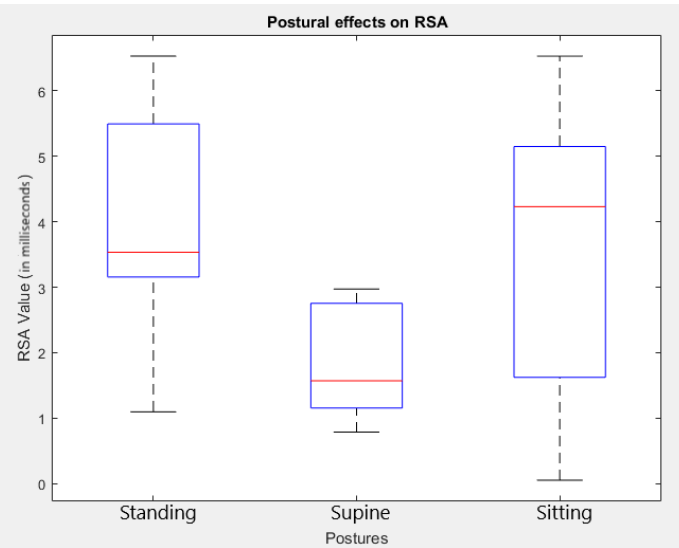


Figure 5: Box Plot of Each Posture's RSA Values

Table 1: T-Test Values and Average Calculated RSA for Each Posture

Postures	**Average RSA Value (ms)**	**P-Values (α = +/-5%)**
Supine	1.8763	Supine & Sitting: 13.43%
Sitting	3.5437	Sitting & Standing: 64.31%
Standing	4.0473	Supine & Standing: 3.1%

IV. Discussion

The t-test value obtained from the experiment did allow for the rejection of the null hypothesis in the standing vs sitting case. Whereas it could not be rejected in the comparison of standing vs sitting or sitting vs supine. The null hypothesis states that samples come from a single Gaussian distribution. If it is not able to be rejected it signifies that there is no significant trend or difference in the two populations and that the only differences are due to sampling error. Thus it can be concluded that valid trends can only be observed when looking to compare supine vs standing and not when comparing any of the others.

The body position influences the heart rate per minute. As mentioned earlier, gravity naturally pulls objects downwards. In the body, the aorta is the largest artery, and it pumps blood to the upper and lower extremities of the body. For blood to reach the upper extremities such as the brain, a large force must originate from the heart to do so. In other words, the heart rate must be fast paced to meet the blood demands of the brain. We concluded from our experiment that the standing position resulted in the highest RSA value followed by sitting and lastly, the supine position. When a person stands, their body is vertical and acting against gravity. Therefore, there is a greater need for the body to create enough pressure to send sufficient blood to the brain. Sitting had less of an affect than standing since the body was bent downwards. The supine position had the lowest RSA as expected since gravity was acting in favor of participants. This can also be due to the body's need to regulate heart rate when standing more due to having more physical activity when standing in general. When in a supine position the person is most likely going to sleep and thus would not need as much heart rate regulation as the body looks to maintain a stable heart rate. Thus, the difference in heart rate was the lowest at this position and the breathing was also easier as air enters the nasal cavity and pharynx better at when the body is equally elevated; the nose is the highest point in the body.

The relationship between body postures with RSA is extremely important when dealing with senior individuals undergoing cardiovascular issues. Quickly changing body postures can cause light headedness or even cause the individual to faint [6]. This is due to the RSA delay disabling the heart from functioning at full capability and unable to pump sufficient blood to the brain [6]. With younger individuals the heart is strong enough to undergo this posture change and pump enough blood to the brain, however, when seniors have weak and aged cardiovascular organs that can cause severe heart problems.

Errors could result from each participant having a different effect on the experiment differently as a result of inter-subject variability. Firstly, the complete prior medical history of each was unknown and that could have resulted in unintentional or biased data; all participants could have had existing breathing or heart complications that were unknown at the time of testing. Furthermore, due to the inaccuracy of the lab BioRadio's, any interference such as noise could have immensely skewed results. It is known that the ECG is affected [3]. Another error in the lab could have been due to the experimental design. In the lab the supine position was done on top of rolling chairs. This meant that the person in the supine position would be tensed up trying to avoid falling. This could lead to skewed ECG signals and breathing data as the body and as a result, heart was working to stay tense. Another error that could have come within the lab was the consistency of the setup. The electrodes were placed on each person in a general area but there was not a consistent marker to know exactly where to place the electrodes. This variability in the placement of the electrodes could have led to errors and variability between people.

To avoid errors, the instructions provided to the participants can be much more precise. Participants may have a physical examination prior to the testing to ensure that the medical history shows no complications in factors that can affect results. Finally, larger sample sizes should be implemented to provide greater confidence in the results.

In terms of our results, we noticed that our initial hypothesis was correct. Standing had the largest RSA value, followed by sitting and lastly, laying down in the supine position. These results are highly probable and seem valid due to the

V. CONCLUSION

The study has shown that certain postural changes when breathing can affect the RSA. The data shows that the average RSA values were 1.8763, 3.5437 and 4.0473 for the supine, sitting and standing positions respectively. To determine a more accurate relationship between the effects of postural change on RSA, the trials would require more testing with a larger sample size. With increased accuracy, more data can be collected to also determine what postures put less strain on the heart rate.

There exist some practical applications of our study. The results we obtained can be used in future research; knowing which positions increase heart rate is very useful. This will decrease the pressure on the heart and increase the quality of life of patients and make them more cautious of performing aerobic activities that suddenly increasing breathing and heart rate.

Future research can be continued to see the effects of additional variables such as both genders and different ages on the medical phenomena of RSA. The effect of exercise is another research of interest when studying RSA.

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