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Biofeedback Device Final Paper

Author Contributions: Ryan conducted the MatLab processing and data analysis after the experiment. Nghia helped with data analysis and worked on the discussion and abstract.

Abstract:

In the modern world, as people spend more and more time sitting down, bad sitting posture has become a crucial risk factor for numerous adverse health outcomes. One aspect of health that could be heavily impacted by posture is respiratory functions. This study investigated the effects of bad sitting posture on respiratory activity in participants through measurements of chest cavity movements using a motion capture system. A statistically significant difference was observed in the respiratory activity of participants in bad and good posture. The findings suggest that bad sitting posture could potentially contribute to restriction in pulmonary function, negatively affecting health and life quality.

Introduction:

Posture plays a major role in the respiratory system. According to one study by Zafar et al., head and neck posture have immediate influences on respiratory function [1]. Respiratory exercises such as forced breathing have even been used to alleviate chronic back pain, much of which is caused by poor posture [2]. The movements of the chest cavity and surrounding body parts during respiration could be taken advantage of when analyzing the respiratory system when someone takes a breath. Ideally, the size of a person's chest cavity changes in proportion to the effectiveness of their respiratory system. According to Denis Hadjiliadis from Medline Plus, the enlargement of the chest cavity creates a vacuum, which pulls air into the lungs [3]. The more the chest cavity enlarges, the more air that is pulled in. In this experiment, the group will study the relationship between posture and respiratory function. This will be done by taking advantage of the expansion of the chest cavity during respiration and relating the size of this expansion to posture. Through the use of this study, those with back pain from poor posture could correct their posture and relieve their back pain by introducing frequent breathing exercises into their daily routine.

Background:

More and more people are spending their time sitting down. Whether it be at their desk at work all day long, or coming home to sit and watch TV, sitting comprises a lot of the average person's day. Ussery et al. found that one in four Americans spend over 8 hours a day sitting [4]. This prolonged sitting has caused an increase in musculoskeletal discomfort in office workers [5]. In addition, more and more people are using handheld devices. By nature, these handheld devices cause people to look down on their screens more often. This increase in time spent looking down is contributing to an increase in neck and spinal discomfort [6].

Bad posture is the main cause of back pains and multiple other spinal disorders. In addition to back and neck conditions, other negative impacts that come with a bad posture are poor balance, headaches, breathing difficulties, joint and disc degeneration, neck, and shoulder pain and it has even been linked to depression[7].

Because of this issue, there has been a rise in ergonomic design in the office workplace. Companies want to prioritize their employee's health and well-being and ergonomically designed chairs are helpful in that they are designed to improve the posture of the user. However, these ergonomic designs are only moderately helping the issue. In the end, the user has autonomy in how they position their body [8]. Many people sit in these ergonomic chairs improperly, making their ergonomic design ineffective. In addition, ergonomic furniture has a high price tag compared to normal furniture, making it less accessible to users. The COVID-19 pandemic has created a shift in companies working remotely at home where this sitting postural problem was perpetuated. In a study done by Preparation H, Americans reported spending on average twice as much time sitting during the pandemic compared to their daily life before the pandemic, with three-quarters of Americans reporting that their home office gave them pain and discomfort.[9]

Our study will determine how posture affects the respiratory activity of a person. It is important to understand lung mechanics when talking about how the respiratory system relates to posture. Upon inspiration, the body is designed to increase the chest cavity through the contraction of respiratory system muscles. The ribs become elevated which then forces the sternum to move upwards and outwards. The diaphragm also contracts downwards increasing the chest vertically. In expiration, the relaxation of respiratory system muscles brings the chest cavity back to its original size [10]. These movements directly move the outer surface of a person's body, which can be measured using a motion capture system.

Purpose/Hypothesis:

The purpose of this study is to determine the correlation between posture and breathing. Our hypothesis is that the closer a subject's seating position is to 90 degrees with the chair, and 180 degrees from the bottom of the subject back to the head, the more respiration activity the user will have. Using a motion capture biofeedback system, the group can analyze the motion of the subject's body in relation to their breathing to assess how their posture affects respiratory activity. This study will also determine how teaching the user about their posture will affect their breathing.

Finding a correlation between the function of the respiratory system and posture could be impactful for both office workers looking to take care of themselves, or even doctors with patients who suffer from respiratory diseases. Office workers could focus on breathing habits, and take frequent “breathing breaks” to improve their posture and general health. Breathing exercises have been known to be an effective way to increase relaxation, improve mood, and lower pain [11]. Teaching the users about their posture may further increase these benefits. Engineers, Doctors, and Nurses could use this information to find and analyze optimal bedside positions for people with respiratory diseases who may be stuck in a hospital for prolonged periods of time [12].

Methods:

The study will take place in the Musculoskeletal Control and Dynamics Lab. The participants will be a group of five Stevens Students of differing heights, ages, and gender. The study will utilize the properties of the motion capture system in the lab. Five total patches, each with four tracking orbs will be placed on the participants, one on each shoulder, one in the sternum area, and two on the backside of the abdomen, as shown in the figures below. Ideally, these orbs will capture the increase in vertical height of the chest cavity during respiration on the shoulders, and forward length in the sternum.

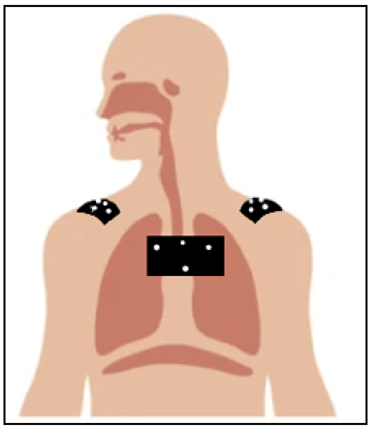

Figure 1: Location of Front Orbs

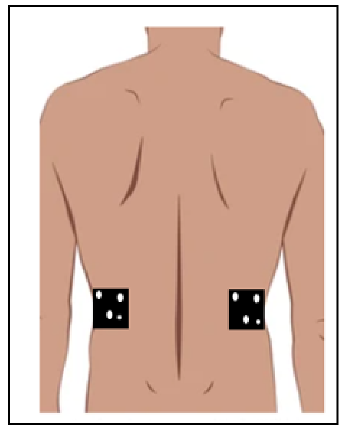

Figure 2: Location of Back Orbs

An example of the sensor setup is shown in the figures below. The motion capture tracking orbs are secured on plastic pads with transport tape and elastic bands.

Figure 3: Front View of Setup

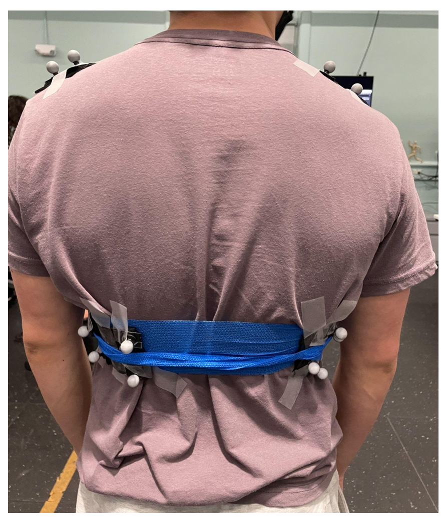

Figure 4: Back View Of Setup

The phases of interest will be breathing during bad posture versus breathing in a taught good posture. First, we will tell them to consciously sit in a bad posture and breathe deeply for 30 seconds. These “bad “postures include combinations of slouching, unbalanced shoulders, and back bending. Then we will teach them to sit with a “perfect” posture and breathe deeply for 30 seconds. The instructions for a person-specific best posture will be given as follows: sit straight up with your head facing directly forwards. Inhale deeply to a count of 3 Mississippi seconds followed by an exhale of 2 Mississippi seconds. Each participant will do four trials: two with bad posture, and two with good posture. The trials are done consecutively.

The experiment setup will have the participant sit on a stool located in the center of the lab, where the orbs will be clearly visible in the motion capture system. The person will not have the monitor in view. The figure below shows two possible scenarios of the participants in the lab, the right side with “person-specific best posture” and the left side with “bad” posture.

Figure 5: Experimental Setup in the Lab

Data will be streamed from the optical motion capture system to Matlab. In Matlab, the group will take all of the position data and fit it to an ellipsoid of best fit. This ellipsoid will be used to mimic the lung cavity. The Volume of the ellipsoid at each instantaneous point during the trial will be captured and graphed. The change in Volume of this ellipsoid of best fit will represent the Inspiratory Capacity (IC), the maximum volume of air that can be inhaled during normal breathing of each participant. It is important to note that because the measurements are taken outside of the body, the change in volume will differ from the actual change in volume experienced inside the chest cavity. Therefore we expect the Inspiration Capacity to be lower than the typical averages for males and females. In addition to the Matlab procedure, videos the motion capture system provides will be analyzed in Mokka but not viewed by the participants until after the duration of their study. After the statistical analysis is finished, the data together with graphical videos captured will be presented to the subjects to demonstrate the detailed relationship between posture and respiration activity. The participants will be able to view this data and the Mokka video and see what a good “person-specific best posture” is, and how this could enhance their respiratory activity.

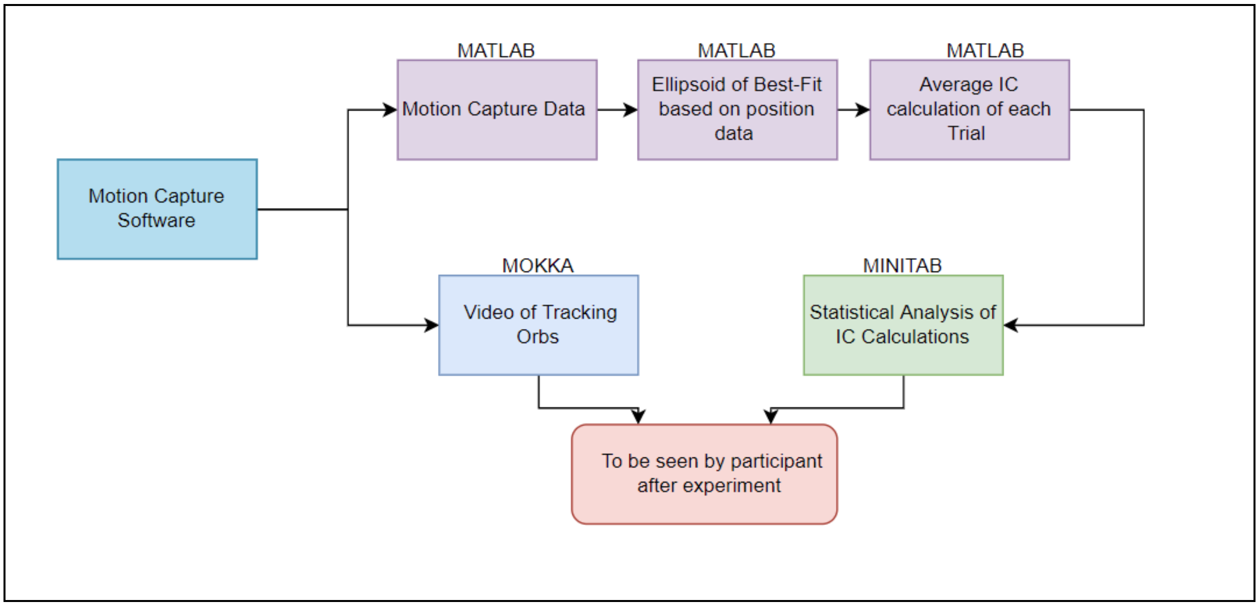

Figure 6: Main elements of the experiments

This experiment does not pose any real risk to the participants. Unwanted touching with the placement of the orbs on the participant's chest may arise as an issue. To avoid this we could give the option for the participants to place the orbs on themselves with verbal guidance.
Paired t-tests are conducted to compare change in chest cavity volume between postures of each participant. An one-way ANOVA test will be employed to analyze the data collected from all participants.

Results:

As mentioned above, the volume of ellipsoids created were captured and graphed at all data points. Examples of such graphs could be seen in the figures below.

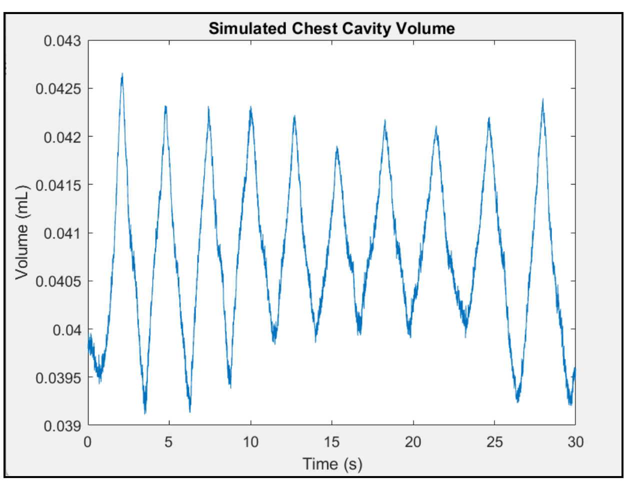

Figure 7: Data from Trial 1 (Good Posture) of Participant 1

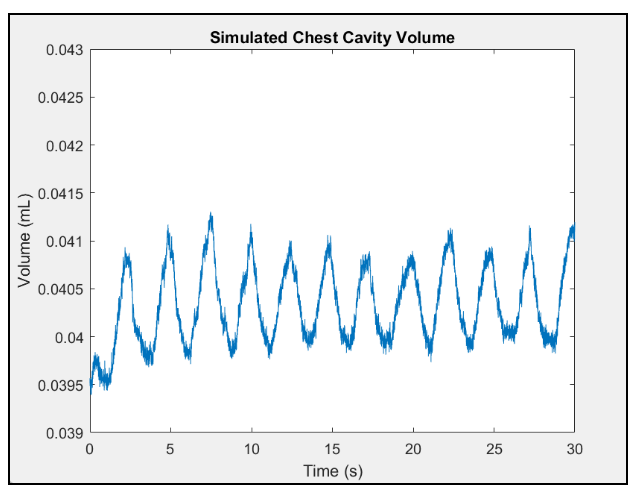

Figure 8: Data from Trial 3 (Bad Posture) of Participant 1

Data collected from each run could be found in Table 1 below. Trials with participant 2 are excluded due to symptoms and recent contact with Covid-19. A scatterplot of all the data could be seen in Figure 9.

Table 1: Raw data of participants

		Change in Chest Cavity Volume (mL)	
		Good Posture	Bad Posture
Participant 1	Run 1	271.3505	130.8531
	Run 2	268.4101	139.8412
Participant 2	Run 1	Inconclusive	Inconclusive
	Run 2	Inconclusive	Inconclusive
Participant 3	Run 1	174.1337	74.2539
	Run 2	153.2432	87.2324
Participant 4	Run 1	505.0324	225.831
	Run 2	419.7418	214.361
Participant 5	Run 1	247.3225	162.7519
	Run 2	245.3011	163.4224

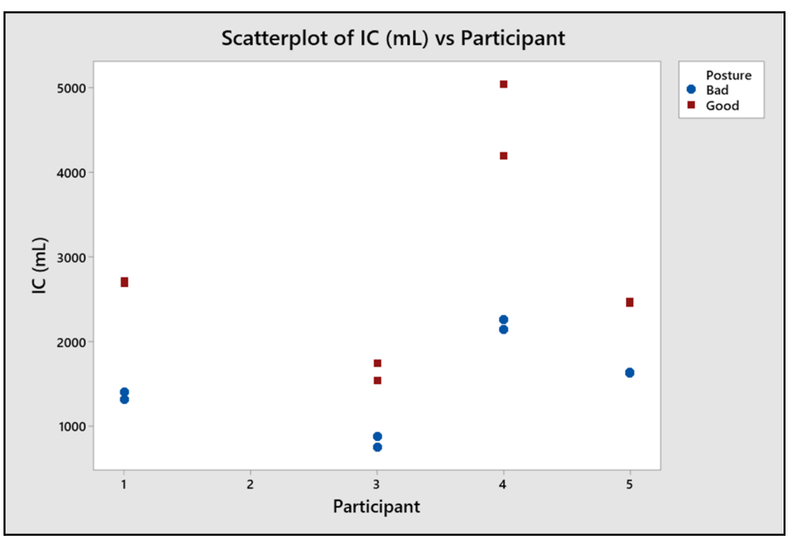

Figure 9: Scatterplot of data from all participant

The results of the analysis tests conducted are shown in the tables below. Table 2 displays the results of the paired t-tests, and Table 3 is the result of the ANOVA analysis.

Table 2: Paired t-tests result (a=0.05)

	Two-tail P value
Participant 1	0.0282
Participant 3	0.1282
Participant 4	0.0962
Participant 5	0.0103

Table 3: Result of one-way ANOVA (a=0.05)

SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Good	8	2284.535	285.5669	14239.34		
Bad	8	1198.547	149.8184	2911.748		
ANOVA						
ce of Varia	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between G	73710.68	1	73710.68	8.595453	0.010933	4.60011
Within Grc	120057.6	14	8575.542			
Total	193768.3	15				

Discussion:

Looking at the raw data, in all cases ICs were higher when the participants were sitting in a good posture. However, results from paired t-tests were inconclusive. There were significant differences in two participants (Participant 1 and 5), while the results were inconclusive for the other two (Participant 3 and 4). This could be due to the lack of data collected, and a more conclusive result could be achieved with more trials between each participant. One-way ANOVA test showed that there is a statistically significant difference in respiration activity between good and bad postures. The average difference of means was around 1450 ml.

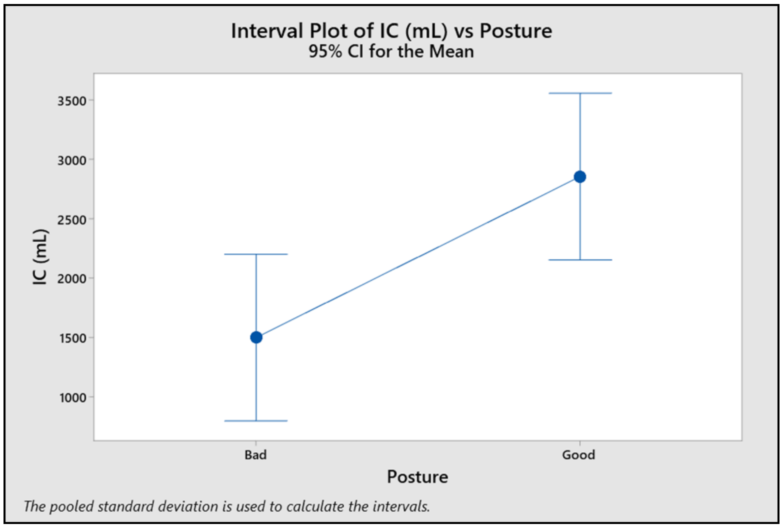

Figure 10: Interval plot of IC vs Posture

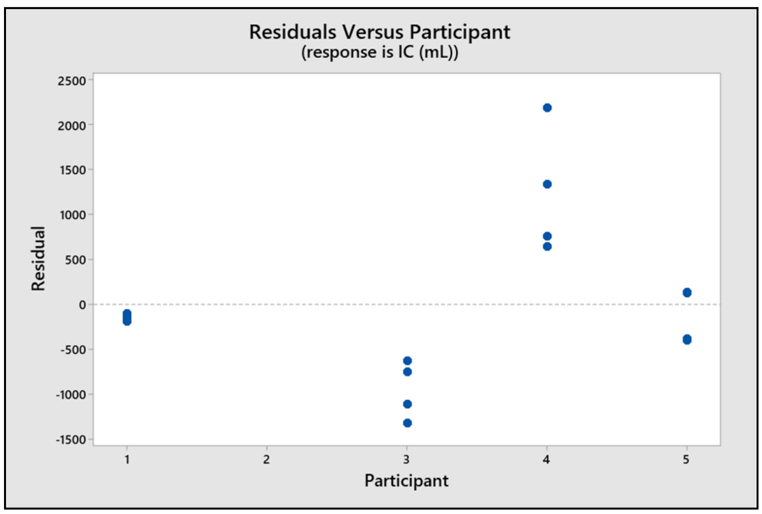

Figure 11: Residuals vs Participant scatterplot

In this experiment, the effects of posture on breathing are analyzed. It can be seen that in a person-specific best posture, all participants had a higher change in volume as opposed to in a bad posture. After the participants were instructed on what a good posture is, and viewed how their posture looked in the Mokka video, they could learn what a good posture is, and use this to enhance their respiratory activity. Students and workers could take breaks while sitting at their desks and sit in this taught “person-specific best posture” for increased respiratory activity leading to increased relaxation, improved mood, and lower pain [11]. This data could also be taken into account in clinical settings. Biomedical Engineers could use this information to create devices that make the user sit in a person-specific best posture or let the user know when they are not sitting in this ideal posture. Doctors and Nurses could use this information to position patients with respiratory diseases who may be stuck in a hospital for prolonged periods of time in a person-specific best posture, although more studies may need to be done to analyze sitting down versus laying down as many hospital patients are positioned.

One limitation of this study is that only the change in the outer surfaces of the body could be measured. While the ellipsoid of best fit is meant to approximate the human chest cavity, in reality, it is not the same. The tracking orbs do a good job of indicating the movement of the shoulders, sternum, and back but the change in motion does not directly correlate to the change in chest cavity size. While it is related, it does not give the exact volumes or changes in volumes of the chest cavity. A higher fidelity measurement method could be employed for a more accurate assessment of lung capacity during different postures. Spirometry is commonly used for such measurement. Bias could also affect the validity of the data collected. In the future, the team could improve on the protocols given to participants to better eliminate bias in the process. The project focuses on specific postures for ease of comparison and replication. However, for future development, a more developed algorithm could be employed for better posture identification and classification, which would result in a better correlation between specific posture and respiration activity.

Overall, the experiment provided the team with an opportunity to learn more about biomechanical sensors, especially motion capture equipment. The coding aspect of the project also helped members expand their knowledge on Matlab. The project introduces the team to scientific study with public engagement, how to conduct such studies, and future improvements that could be implemented. In conclusion, the project not only sparks interests in research of biofeedback/biomechanics topics, but it also provides the team with valuable skills and knowledge for the future.

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