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Lab 603 Group 7

A Quantitative Inquiry into the Effects of Exercise with Chronic Obstructive Pulmonary Disease

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Abstract

Eleven individuals were tested to determine the effect of obstructed breathing on heart rate, percent saturation oxygen, blood pressure, and rate of perceived exertion during exercise. The obstructed breathing was intended to simulate chronic obstructive pulmonary disease. The individuals served as their own control as both obstructed and unobstructed values were obtained. Participants engaged in 4 minutes of biking at 50 RPM and a set resistance, and after 4 minutes, the intensity was elevated to 70 RPM for 4 additional minutes. After the exercise data were obtained, a 5 minute rest period was observed to ensure the participant returned to resting levels. Statistical tests showed that there was a significant difference in percent oxygen saturation and rate of perceived exertion during obstructed exercise versus unobstructed. Although there was not a statistically significant difference for heart rate and mean arterial blood pressure, there was a general increasing trend. It was therefore concluded that obstructed breathing resulted in greater exertion of the heart, leading to physiological changes that can be extrapolated to chronic obstructive pulmonary disease (COPD).

Introduction

Chronic obstructive pulmonary disease or COPD is a major cause of illness and mortality worldwide. COPD is a systemic disease, characterized by endurance exercise intolerance. While controversy exists about the main physiological determinants of the impaired capability for exercise, the traditional view is that exercise tolerance is reduced through perceived respiratory difficulty, originating as a reduced lung capacity during inspiration and affecting the functions of various systems throughout the body (Couillard, 2010). It has been previously determined that a systemic effect of COPD can be seen during exercise through increased cardiovascular stress and decreased endurance (Probst, 2006). Studies have employed various methods to determine the cause of this increased stress. In healthy exercising individuals, the active muscles provide the largest need for oxygen, a need that the cardiopulmonary systems can keep up with during moderate exercise. Normally these locomotor muscles are composed of predominantly slow-fatiguing, oxidative muscles. Findings in COPD subjects have demonstrated a strong correlation between the excess stress on the cardiovascular system and a decreased flow of oxygen to active muscles. The body is able to combat this lack of oxygen in the peripheral muscles through an increase in fast glycolytic fibers and a decrease of needed oxygen. While conversion to fast gylcolytic fibers allows the muscles to function on lower levels of oxygen, the increase in glycolytic fibers also increases the acidity of the muscle due to lactic acid production, shortening the time to fatigue (Amaan et. al., 2010).

The decrease in oxygen available to the muscles can be explained in part by vasoconstriction of the peripheral blood vessels and the re-routing of blood oxygen from active locomotor muscles to the respiratory muscles to cope with the increased demand seen in COPD (Harms, 2000). It has been hypothesized that the hyperinflation of resting lungs in COPD subjects decreases their ability to inspire additional volumes of air when called for during exercise (O'Donnell, 2008). The lack of available oxygen coupled with the increased demand during exercise has been shown to put additional strain on the cardiovascular system manifesting itself in long-term effects such as impaired coronary blood flow (Selcuk, 2009) and an increased rate of cardiovascular disease (Sata, 2009).

An obstructed breathing simulation will be performed on subjects as a simulation of COPD. It is the goal of this study to use an obstructed breathing apparatus paired with whole body exercise (Probst, 2006) to study the response of the cardiovascular system to increased work of breathing (simulated COPD). If the study is successful, the percent oxygen saturation of each subject should be significantly reduced with obstruction but remain normal during unobstructed exercise and rest. We hypothesize that due to the simulated increased work of breathing, subjects will exhibit increased cardiovascular stress as manifested through an increased heart rate and blood pressure as well as increased rate of perceived exertion (RPE). Due to the sympathetic innervations, we hypothesize that the MABP will remain constant or have a slight increase. We hypothesize that the RPE will show positive correlation to heart rate.

Materials and Methods:

Blood pressure, percent oxygen saturation (pO_2), heart rate, and rate of perceived exertion (RPE) were measured while biking in order to determine the physiological implications of simulated COPD. Blood pressure was measured using a sphygmonanometer. A pulse oximeter indicated the subject's percent oxygen saturation and heart rate, while a standardized RPE scale (6-20) was used to assess the participant's rating of perceived exertion.

Each participant was required to give informed consent and demographic data were collected. Order of exercise with or without obstruction was determined via coin toss. The stationary bike without moving handlebars was used with the resistance set to level two. Participants sat on the bike with their left hand rested at heart level and their right hand rested on the bike. The left arm was used to take manual blood pressure and the right index finger was used for pulse oximeter readings. A graphical representation of the RPE scale, containing the numbers 6-20 was posted in front of the participants throughout the trial. This scale provided a quantitative method for participants to express perceived workload. The 6-20 scale was chosen because correlates to heart rate measurements, with 6 being the lowest RPE and a typical resting heart rate.

After collection of resting measurements, participants were asked to apply the nose clip and insert the mouthpiece. As determined via coin toss, each participant was assigned either obstructed or unobstructed trial first. The participant began cycling for eight minutes, the first four minutes at 50 revolutions per minute (RPM) and the second four at 70 RPM. Each participant received a five-minute break between the completion of phase one and the start of phase two. Phase two then consisted of the same parameters with the participant performing the unperformed trial (either obstructed or unobstructed).

Percent O_2 saturation, heart rate and RPE was taken at minutes 0, 2, 4, 6, 8, 10, and 12. Blood pressure was taken at minutes 0, 4, 8, 10, and 12. The two sets of measurements on each participant allowed for each participant to serve as their own control. We compared the differences between the physiological measurements during obstructed breathing and unobstructed breathing in order to make conclusions.

In order to attain the most accurate heart rate and percent oxygen saturation readings it was found that the participants could not put weight on the hand attached to the oximeter while measurements were being taken. Instead they were told 15 seconds before each measurement to turn their hand over palm-up until and accurate measurement could be attained. Measurements were determined to be accurate though comparison to manual measurements taken on either the carotid or radial artery.

Independent t-tests were conducted to compare obstructed breathing and unobstructed breathing measurements with a significance level alpha = 0.05. To determine if subjects returned to basal resting levels an independent t-test was conducted to compare initial rest and intermediate rest (between trial 1 and 2). Once again alpha = 0.05 was used as significance level. With resting measurements it was determined that a $p>0.05$ would show a return to resting levels while $p<0.05$ would show a significant difference between initial and intermediate rest levels.

Results:

Original Procedure:

Results were obtained from 6 females and 5 males in both unobstructed and obstructed breathing. In order to see values throughout the body, blood pressure measurements were converted into mean arterial pressure as well as studied as systolic and diastolic separately. Appendix A includes the complete data set.

From these data, independent t-tests were conducted to compare obstructed breathing and unobstructed breathing measurements and subsequently p-values were calculated.

The data at minute 4 (50 RPM) for unobstructed and obstructed were compared using the independent t-test. Significance was found in the percent O_2 saturation (p=0.0026) (Figure 1) and RPE (p=0.0165) (Figure 2). Mean arterial pressure (p=0.2305) (Figure 3) and heart rate (p=0.1321) (Figure 4) were not statistically significant.

At minute 8 (70 RPM) significance was found for percent oxygen saturation (p=0.004) (Figure 1) and RPE (p=0.0299) (Figure 2). Mean arterial pressure (p=0.4404) (Figure 3) and heart rate (p=0.1698) (Figure 4) were not statistically significant.

To determine whether measurements after exercise returned to resting levels, a t-test was conducted comparing resting values to 4 minutes after exercise (minute 12). The following p-values were statistically significant for the heart rate (p=0.00000467) and RPE (p=0.0209). Mean arterial pressure (p=0.2380) and percent O_2 saturation (p=0.3133) were not statistically significant. In the case of resting measurements, statistical significance shows that the levels did not return to basal levels while not statistically significant levels show that there was not a significant difference between basal levels and intermediate rest levels, or that the participant did return to resting levels before the second trial occurred.

Although heart rate measurements did not show statistical significance between obstructed and unobstructed, a positive correlation was observed between heart rate measurements and participants RPE (Figure 4) ($R_{Obstructed}$= 0.813, $R_{Unobstructed}$= 0.974).

Table 1: Means and standard deviations for original procedure.

	Minute	**Measurement**	**Mean**	**Standard Deviation**
RESTING	0	Mean Arterial Pressure (mmHg)	87	±10
	0	%Saturation O2	98	±1
	0	Heart Rate (beats/min)	82	±9
	0	RPE	6	±0

			Unobstructed		Obstructed	
	Minute	**Measurement**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
50 RPM	4	Mean Arterial Pressure (mmHg)	96	±11	99	±12
	4	%Saturation O2	98	±1	96	±2
	4	Heart Rate (beats/min)	116	±15	124	±18
	4	RPE	10	±2	12	±3
70 RPM	8	Mean Arterial Pressure (mmHg)	97	±10	97	±11
	8	%Saturation O2	97	±2	93	±3
	8	Heart Rate	142	±20	133	±24
	8	RPE	13	±2	15	±3
STOP	10	Mean Arterial Pressure (mmHg)	91	±9	93	±10
	10	%Saturation O2	98	±1	98	±1
	10	Heart Rate (beats/min)	109	±13	110	±21
	10	RPE	7	±1	7	±1
STOP	12	Mean Arterial Pressure (mmHg)	88	±8	91	±9
	12	%Saturation O2	98	±1	98	±1
	12	Heart Rate (beats/min)	101	±7	100	±21
	12	RPE	6	±0	7	±1

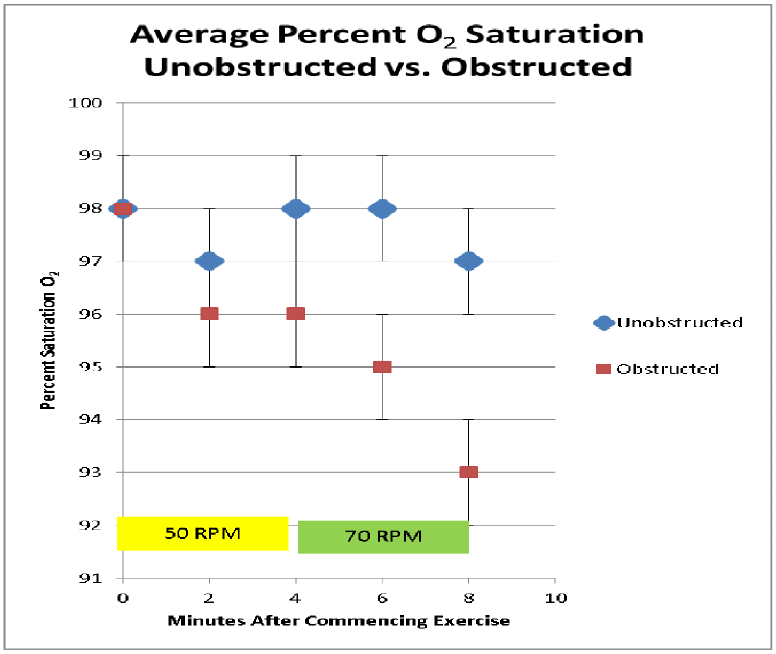

Figure 1: Percent oxygen saturation and unobstructed vs. obstructed breathing ($p<0.05$).

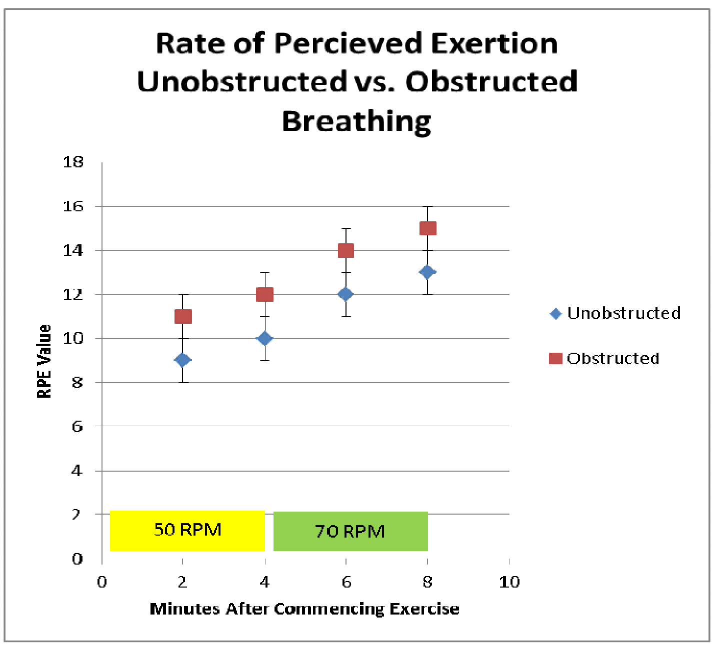

Figure 2: Rate of perceived exertion in obstructed and unobstructed breathing ($p<0.05$).

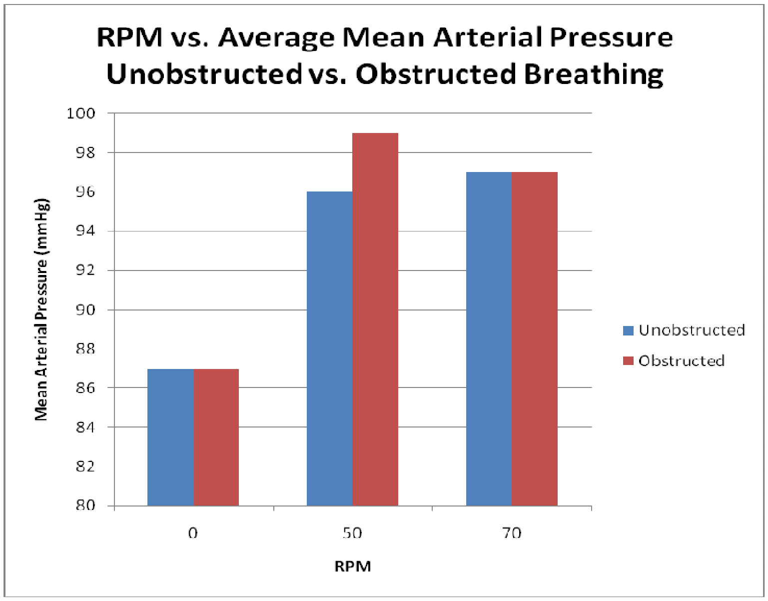

Figure 3: RPM vs. mean arterial pressure unobstructed vs. obstructed breathing (p>0.05).

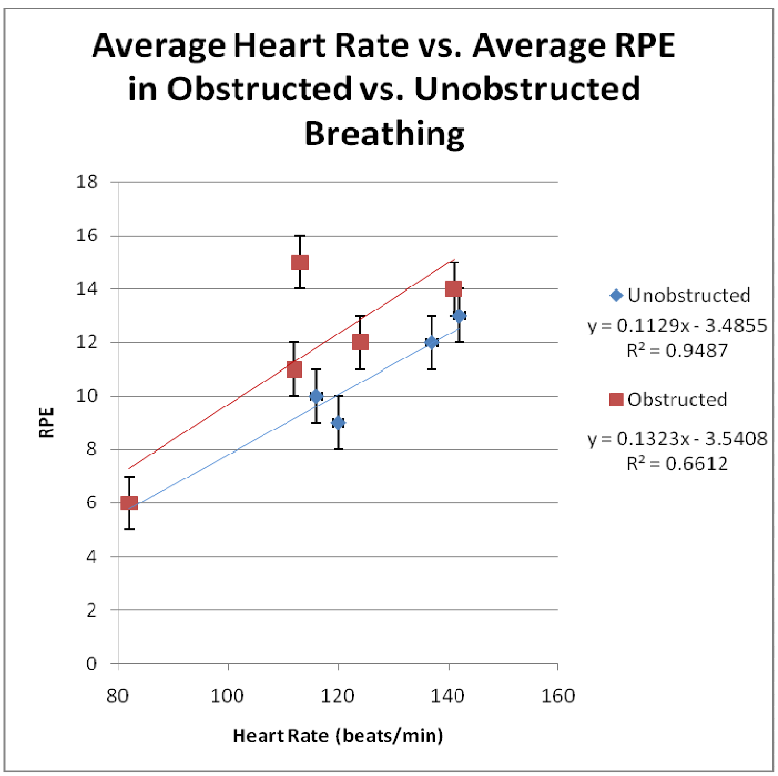

Figure 4: Average heart rate vs. average RPE*10 during obstructed vs. unobstructed breathing.

Repeat Procedure (additional rest):

Upon suggestion three additional participants were studied under a modified procedure to determine if a thirty minute rest period was adequate to return measurements to basal levels. All other procedural aspects remained identical. See discussion for further clarification.

Following the thirty minute rest period, all measurements returned to near resting values for exercise with unobstructed breathing. Heart rate, percent O_2 saturation, and mean arterial blood pressure didn't show statistical significance. ($p>0.05$). RPE was reported as 6 for all participants both at rest and thirty minutes post exercise and therefore was also not statistically significant ($p = 1$).

After the thirty minute rest period after obstructed exercise, RPE, mean arterial blood pressure, and percent O_2 saturation did not significantly differ from resting values. RPE was again reported as 6 for all participants both at rest and thirty minutes post exercise ($p=1$). Percent O_2 saturation and mean arterial blood pressure both didn't show statistical significance ($p>0.05$). However, heart rate was statistically significant from resting values ($p<0.05$).

Table 2: Means and standard deviations of rest values for repeat procedure (additional rest).

Minute	Measurement	Mean	Standard Deviation
0	Mean Arterial Pressure (mmHg)	89	±8
0	%Saturation O2	98	±1
0	Heart Rate (beats/min)	105	±16
0	RPE	6	±0

		Unobstructed Extended Rest Period		Obstructed Extended Rest Period	
Minute	**Measurement**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
13	Mean Arterial Pressure (mmHg)	88	±8	96	±8
13	%Saturation O2	98	±0	98	±0
13	Heart Rate (beats/min)	119	±7	124	±22
13	RPE	7	±1	8	±2
23	Mean Arterial Pressure (mmHg)	85	±4	88	±3
23	%Saturation O2	98	±1	98	±0
23	Heart Rate (beats/min)	106	±13	108	±20
23	RPE	6	±0	6	±0
38	Mean Arterial Pressure (mmHg)	85	±7	83	±6
38	%Saturation O2	98	±1	99	±1
38	Heart Rate (beats/min)	105	±9	97	±13
38	RPE	6	±0	6	±0

Discussion:

Original Procedure:

Our findings suggest a significant effect to both pO_2 and RPE as well as a positive correlation between increased heart rate and increased RPE upon exercising with and without obstruction. It was noted that the pO_2 for the first four minutes of exercise (50RPM) showed significance between obstructed and unobstructed trials ($p<0.05$). Therefore we can conclude that there was a difference between obstructed and unobstructed exercise for percent oxygen saturation. This trend continued at exercise minute eight (70RPM) ($p<0.05$). Percent O_2 saturation was always lower in obstructed breathing during exercise compared to unobstructed breathing as shown in Figure 2. Rational for the drop in percent saturation have been suggested and include a potential arterial/venus shunt in which deoxygenated blood bypasses the lungs and continues on to circulation in high stress situations (Dempsy, 2008).

We also found significance between obstructed and unobstructed RPE values ($p<0.05$) at both 50 and 70 RPM. We noted that the participants remarked that they felt the higher intensity exercise was easier due to acclimation to the obstructed breathing apparatus.

As hypothesized, we did see a positive correlation between heart rate and RPE($R_{Obstructed}$= 0.813, $R_{Unobstructed}$= 0.974), if the RPE value is multiplied by 10 as seen in Figure 3. The RPE scale is designed to correlate with heart rate when multiplied by 10; hence, the 6 to 20 scale. Increasing the intensity of exercise led to an increase in heart rate and RPE in both unobstructed and obstructed breathing trials. Furthermore, RPE was higher at all times during obstructed breathing than unobstructed breathing as seen in Figure 3.

As a whole, the study showed an increasing trend in heart rate, blood pressure, and RPE with a decreasing trend exhibited in pO2 for obstructed breathing compared to unobstructed breathing.

However, statistical significance was not achieved for mean arterial blood pressure measurements ($p>0.05$). This could be due in part to the sympathetic innervations of the heart which cause the heart rate and stroke volume to increase with increased exercise stress but at the same time cause the total peripheral resistance (TPR).

The study of heart rate also did not show significance ($p>0.05$) when a comparison was made between obstructed and unobstructed trials. This result is not surprising as heart rate response can often vary based on the amount of exercise typically performed by a participant (how in shape they are) as well as other extenuating circumstances such as caffeine intake and daily stress levels.

Experimental Limitations:

Our experiment was set up with five minutes of rest to serve as time given to allow the participant to return to resting levels. However, our results showed that five minutes was not an adequate amount of time for rest, since heart rate and RPE did not statistically return to normal resting levels in that amount of time. This could have skewed data collected from the second trial as start levels were not always returned to basal levels before additional exercise began. Recovery period can vary from person to person based on health and fitness. In order to improve the experiment, we would accommodate to a greater population by increasing the rest period.

Sample size also proved to be a limitation to our study. Due to time constraints and length of procedure we were only able to study 11 subjects. A larger population size could have led to more significant or clear results and more overt patterns in results. The effects of the small population size can be seen as well in the large standard deviations in our data (Table 1).

Suggestions for further study:

In regards to other future investigations into the effects of COPD on cardiopulmonary stress during exercise, we would suggest testing different modes of exercise ranging from low impact resistance training to cardio workouts. The study conducted as described in the article by V.S. Probst et al. (2006) investigated the effects of different modes of exercise, specifically cycling, resistance training, and treadmill walking, on the cardiopulmonary stress of COPD patients. It was concluded that the cardiopulmonary stress was in fact much lower during resistance training exercise as compared to both the whole body exercises. Therefore, to further this research and our own conclusions, we would suggest evaluating cardiopulmonary stress in other types of exercise mainly yoga, Pilates, jogging, dance, team sports, and weight training for example. These studies and their ensuing findings could greatly improve the exercise regimens for COPD patients in order to reduce their body stress during their workouts and maximize the exercise's beneficial effects.

Furthermore, we firmly believe that the value of this research would be deeply beneficial as a lesson in the dangers of smoking, an activity that can cause COPD and significantly impair pulmonary function. Implementation of the study for students, especially for middle school children who are approaching the age of making life altering decisions such as the decision to smoke, would be a cautionary eye opening event. Specifically having participants feel the difference in biking under obstructed breathing as compared to unobstructed (healthy) breathing, would hopefully deter any student from harming their lungs with cigarettes. It is one thing to learn about the harmful nature of smoking, but completely another to be able to experience its effects in such a hands on manner.

Overall, we conclude that exercising under obstructed breathing increases heart rate and mean arterial blood pressure, while decreasing percent O_2 saturation. Although not all the results were statistically significant, the data do show conclusive trends. Our conclusions can be extrapolated to patients with COPD because of the increased work of breathing the mouth piece apparatus induced.

Repeated Procedure (Additional Rest):

After thorough analysis of the experimental data, we came to conclude that the original rest period of five minutes in between trials proved inadequate and hence confounded our results. Statistically different heart rates were measured after our rest period ($p<0.001$) allowing the conclusion that heart rate was not able to return to resting levels before the commencement of the second trial. The same observation was also true of RPE ($p<0.05$). In response to this, we set out to perform three subsequent experimental runs making use of an extended resting period of 30 minutes (3 female participants). We hoped that this would be sufficient time for the participant's heart rate and RPE to return to resting and therefore make our results more accurate.

After the experiments were performed and statistical analysis was completed, it was determined that RPE did return to resting levels upon additional rest ($p>0.05$). It was found that following the unobstructed trial and subsequent resting period, the heart rate did return closer to the original resting values compared to the shorter rest time trial runs ($p>0.05$). Increasing the resting period did provide stronger evidence for our claim that obstructed breathing significantly increased heart rate; however, the values did not completely return to resting even after this extended time period ($p<0.05$). In fact, heart rate might not come back to fully resting values until hours after the strenuous exercise is completed. Recovery time varies greatly among individuals and is a hard variable to quantify, predict, and account for. Therefore, we would suggest completing the two trails on separate days to be sure the rest period is not a confounding factor in the final results. Doing the procedure on different days will consolidate the procedure as recovery levels will not need to be taken, so more participants can be included in the study. However, the proposed procedure change may bring up confounding variables due to varying stress, food and beverage intake.

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Appendix C:

Procedural limitations that led to final methods:

As our lab team began the task of putting our experimental procedure into practice, we came across numerous limitations on the way to perfecting our trial methods. Originally, we had assumed that our participants would exercise at one RPM level throughout the entire trial run. Upon further contemplation however, we decided that in order to truly witness an observable difference in cardiovascular responses between the COPD simulated exercise and normal exercise, we should step up the RPM level part way through each trial. Therefore we are able observe and compare two intensities within each trial and among the different exercise simulations. Once the dual intensity trial method was established, we now ran into the problem of selecting the two RPM levels. After much trial and error, it was ascertained that the RPM levels of 60 and 80 would be too strenuous for participants to maintain throughout the duration of the trials, especially while during the COPD simulation. 50 and 70 RPM levels, in our opinion, serve as the optimum levels to monitor cardiovascular changes in our participants without pushing them too far.

In regards to our equipment, our original exercise bike did not have stationary handles. The moving handles would have added several unpredictable confounding variables and would have made taking measurements unpredictable and difficult, so we instead opted for a bike with stationary handles. This stationary handle bike also provided the added benefit of an adjustable resistance that we could manually set to standardize. The previous bike did not have this feature, making our final bike choice optimal.

As our group embarked on fine tuning the time duration of the trial, we also ran into complications. Our initial time length of biking for each trial was set at 3 minutes total with a resting time in between trials of 2 minutes. This timing structure however proved insufficient to collect accurate data and to allow the participants heart rate and blood pressure to return to resting levels before commencing the next trial. Again, the trial and error process lead us to establish the proper timing of 4 minutes for both RPM levels in each trial (8 minutes total) with a resting period of 5 minutes. Further research experiments could extend the duration of the experiment in order to be able to track cardiopulmonary changes to a higher degree and investigate the body’s responses over time to a greater extent.

In addition, the actual collection of data proved problematic as well. Our lab group has access to an electronic blood pressure cuff, which we assumed would take the resting and exercising blood pressure in theory. In reality however, the electronic cuff cannot accurately take the blood pressure of an exercising participant; therefore, we will need to use a manual cuff to take the blood pressure during exercise. Furthermore, the pulse oximeter measurements needed adjusting as well since during our preliminary testing trials, the heart rate readings were extremely low, and about half of what the heart rate should be. We soon discovered that the participant cannot put pressure on the hand hooked up to the meter. Instead, he or she needs to place their hand palm up and rest it on the bike handle while measurements are taken so as to get accurate results. If during subsequent trials the heart rate seems off again, we will resort to taking the heart rate by hand either on the carotid pulse or the radial pulse as a backup measure. One further minor complication is in regards to the nose clips our participants wear during the experiment. They have a tendency to slip off but when this occurs, the participant can manually hold their nose closed until we can replace the clip for them. Something to consider moving forward would to fine tune the breathing apparatus to maximize efficiency and comfort for the participants.