The Effect of Hyper-Oxidative Breathing on Physical Endurance

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KEYWORDS: blood pressure, exercise, heart rate, hyper-oxidative breathing, physical endurance, physical stress, wall-sit

ABSTRACT:

Increasing endurance can have important implications for anyone looking to improve their physical performance. Hyper-oxidative breathing techniques, such as the one utilized in the Wim Hof Method, have been proven successful in improving endurance in individuals. This study explores the physiological effects of a hyper-oxidative breathing technique, based off of the Wim Hof Method, on physical endurance. The physiological parameters observed were heart rate, blood pressure, as well as wall-sit duration, in seconds. The BIOPAC student lab system (BSL 4 software, MP36) was used in this experiment. Blood pressure was measured by utilizing an “OMRON 10 Series +” automatic blood pressure monitor (BP791IT, OMRON, Inc.). These effects are measured by implementing the breathing technique during an anaerobic exercise, a wall-sit, under normal, non-extreme conditions. Participants performed two trials of wall-sits, one without the breathing technique, then another one week later with the breathing technique. It was found that the breathing technique was effective in elongating the duration of a maximal-effort wall-sit for the entire group of participants as a whole. The heart rate data recorded during the initial wall-sits without the breathing exercise plateaus earlier, at 40 seconds, than the normal breathing heart rate, further indicating that Hof’s breathing technique is effective in obtaining and maintaining a stable heart rate more quickly. However, based on the statistical analysis, this is not statistically significant. This trend observed, however, is an important observation seen in the data, and had the equipment in this experiment been more reliable and if more trials were run with a sample size larger than 50 people, this data could have been statistically significant. We conclude that while our data indicates that the breathing technique did successfully raise the duration an individual could maintain a wall-sit, further studies are needed to determine exactly which physiological changes give rise to this increase.

INTRODUCTION:

Exercise has been found to stabilize mood, improve self-esteem, and improve cognitive function from increased blood flow to the brain (Sharma *et al.*, 2006). Moderate and regular exercise in particular has been associated with disease prevention and this exercise immunology may improve chronic illnesses, chronic heart failure, malnutrition and inflammation (Rosa Neto *et al*., 2011). By researching exercise through breathing patterns and techniques, we seek to better understand the correlation between oxygen consumption, the SNS, and the immune system. With this knowledge, we can improve the physical endurance of individuals, and begin to create a more holistic overall wellness. This could have the potential to gradually decrease the amount of medical attention sought out and overall decrease mortality rate, which will have a positive impact in our healthcare system.

There are two different types of exercise the human body experiences during physical exertion: aerobic (with oxygen) and anaerobic (without oxygen). Typically, aerobic exercise is associated with cardio and long-interval exercise that requires increased heart rate and blood pressure to pump oxygenated blood to working muscles. Anaerobic exercise consists primarily of weight training and short-duration bursts of exercise that form lactic acid within the muscles. In this short-duration/high-intensity exercise, there is the breakdown of muscle glycogen to glucose to contribute to oxidative phosphorylation. Simultaneously, as the intensity of anaerobic exercise increases, so does the production of adenosine triphosphate (ATP) by glycolysis, as well as the production of lactic acid. Fast-twitch fibers, specifically fast-oxidative glycolytic fibers, are the primary source of this production (Widmaier *et al.*, 2008). Oxygen from the blood is necessary for the production of ATP within these fibers, and is also needed as an energy source at the end of anaerobic exercise to return muscle fibers and interstitial fluid oxygen concentrations to their original state. Additionally, oxygen is also required in order to metabolize lactate made during exercise (Widmaier *et al.*, 2008). Anaerobic exercise is limited by cardiac output, the respiratory system's ability to deliver oxygen to the blood, and the muscles' ability to use that oxygen (Widmaier *et al.*, 2008). The requirement of oxygen is a limiting factor during exercise that we can target in order to improve physical output.

The SNS plays a vital role in the adaptations made by the human body during extended periods of anaerobic exercise. The SNS promotes vasoconstriction, and an increase in heart rate. Together these result in decreased parasympathetic activity to the sinoatrial (SA) node of the heart and increased sympathetic activity. In combination, the limitations regarding oxygen levels during anaerobic exercise are diminished. Conversely, the SNS also supports vasodilation of the skin occurs in order to dissipate heat (Widmaier *et al.*, 2008). Provided this information, we can hypothesize that inducing a response of the SNS before exercise would allow for the body to increase its endurance during anaerobic exercise by promoting better oxygen absorption into the bloodstream. This would increase the production of ATP and lower the differential of oxygen concentrations within the muscle fibers and interstitial fluid before and after exercise; therefore decreasing fatigue. Wim Hof, an extreme athlete, has methodized how to suppress the innate immune response by increasing heart rate and adrenaline levels to protect against extreme cold conditions (Hof *et al*., 2017). Experimentation of Hof's breathing technique has shown an increase of cortisol from the SNS, which suppresses the natural response of the immune system by decreasing the overall production of inflammatory cytokines upon exposure to pathogens (Kox *et al*.,2014; Pickkers *et al*., 2011). Hof's techniques function to influence the innate immune response by overall manipulation of the SNS; inducing a fight or flight response mediated by the SNS to supply increased blood flow to the muscles, internal organs, and brain (Maestroni, 2006; Hof *et al*., 2017). This focus will improve the uptake of oxygen during anaerobic activity, which is coupled linearly with cardiac output (Lewis *et al.,* 1985).

In this study, we will be exploring the possible benefits of the hyper-oxidative breathing technique during an anaerobic exercise under normal, non-extreme conditions. This will be tested through quantifying the performance of a maximal effort wall-sit exercise until muscle fatigue is reached. Each participant will first complete the task while breathing without instruction; the task will again be performed using the designed hyper-oxidative breathing technique one week later. By measuring the time until muscle fatigue is reached, change in blood pressure, and change in pulse, we will be able to assess the benefits of the hyper-oxidative breathing technique has on endurance during anaerobic physical exercise. The data collected will give us a better understanding of the contribution breathing has on oxygen uptake. This has the opportunity to encourage the development of future studies on improving overall physical wellness by further exploring the relationship Hof's breathing technique holds with the SNS's effects on physical output.

MATERIALS:

The variables in this experiment were utilized to determine if a hyper-oxidative breathing technique will allow for an individual to hold a wall-sit for a longer period of time than before practicing Hof's breathing technique. The physiological parameters observed were heart rate, blood pressure, as well as wall-sit duration, in seconds. The BIOPAC student lab system (BSL 4 software, MP36) was used in this experiment. Blood pressure was measured by utilizing an "OMRON 10 Series +" automatic blood pressure monitor (BP791IT, OMRON, Inc.). The BIOPAC Systems, Inc. Student Manual (ISO 9001: 2008, BIOPAC Systems, Inc.) was used as a guide to measure and analyze blood pressure readings. Heart rate was determined by using a pulse oximeter/carbon dioxide detector to record the beats per minute (Model number:

9843; Serial Number: 118102981; Made by Nonin Medical Inc., Minneapolis, MN, USA). The last variable, wall-sit duration, was measured by using a basic stopwatch on an iPhone.

METHODS:

Screening and Consent

A sample size of 50 participants, ages of 20-27, were recruited on a voluntary basis from the Physiology 435 Lecture 001 at The University of Wisconsin-Madison. Physiological measurements were collected at the UW-Madison Medical Sciences Center. A consent form was signed by all participants prior to their participation that outlined the purpose of the experiment, confidentiality measures, and the potential risks of the experiment.

Procedure

Anaerobic exercise was chosen in this experiment because it is quick and easy to perform in an experimental setting. A wall-sit was chosen for this experiment because this type of exercise is hard to manipulate and it is easy to standardize amongst all participants. The wall-sit can also be easily taught which is ideal in an experimental situation.

Information was collected from the participants, in the form of a questionnaire, prior to the experiment including: age, gender, amount of current physical activity, as well as health information that was necessary to know prior to the students participating in the study. Students were excluded from the study if they had the following criteria: Asthma, previous heart problems, any previous lower extremity injuries, or any condition that prevents one from participating in physical activity. Students who indicated that they had asthma prior to the experiment were not included, as this study relied on physical activity and an asthma attack could easily result.

The experiments took place in two experimental increments, with each being exactly one week apart (**Figure 1**). The participants were informed to return to the same location, at the Medical Sciences building on campus, at the same time and on the same day 7 days after the first round of experimentation.

The resting blood pressure and pulse were taken for each participant prior to the testing, this information was collected and placed into a Microsoft Excel spreadsheet. The blood pressure cuff was placed on the upper right arm of each participant. Each participant was instructed to roll up their sleeve if the material of their clothing was too thick to get the blood pressure reading. Each participant was also instructed to sit with their legs uncrossed with their feet flat on the ground and their palms faced up, in order to get the most accurate reading. During the blood pressure measurement, the resting heart rate was also recorded for each participant. The students were instructed to place the pulse oximeter/carbon dioxide detector finger clip on their left index fingers, and the beats per minute was recorded for each one.

After the initial, resting measurements were taken, each participant was to stand with their feet hip-width apart and squat against the wall with their knees at a 90-degree angle in order to begin a "wall-sit." Each participant was instructed on how to do a wall-sit and was told when to stop bending their knees at a 90-degree angle. Participants were instructed to hold the wall-sit for as long as possible, or until 100 seconds, whichever came first, and to slide down to the ground when they could no longer hold the wall-sit. The pulse oximeter was clipped to the left index finger of each participant for the duration of the wall-sit, and the pulse (bpm) was read and recorded every 10 seconds until the end of the wall-sit (**Figure 1**). This data was placed in a Microsoft Excel spreadsheet. The wall-sit duration was also recorded for each participant. The blood pressure was recorded again immediately after the wall-sit for each participant in the same manner as mentioned above.

At the end of the first round of wall-sit trials with the participants, each participant was shown a powerpoint that explained how to perform a hyper-oxidative breathing technique adapted from the Wim Hof Method. The powerpoint explained the steps of the Wim Hof Method to each participant; they must perform 30-40 power breaths: deep breathing in and out through the mouth, full inhales, but do not exhale all the way. While inhaling, it is explained that each participant should feel their stomach rise and on the exhale they should feel their stomach fall. Then each participant is told to take an eight second inhale and then an eight second exhale (Hof 2016). The participants were taught these techniques directly prior to the second round of trials for the experiment, which were conducted exactly 7 days after the first trial, on the same day and at the same location and time.

At the second round of trials, where the participants were taught the breathing exercise, the same procedure outlined above was repeated. The initial and final heart rates, initial and final blood pressures, as well as the wall-sit durations were recorded for each participant once more.

Data Analysis

Upon the completion of the experiment, the data for heart rate (HR), duration of wall-sit, and blood pressure (BP) for both baseline (normal breathing) and the experimental data (exercise breathing) trials were gathered for analysis. In order to determine whether a significant difference existed between the baseline and the experimental data, two-tailed paired t-tests were performed to find p-values. A p-value of 0.05 or less was required to be considered significant. Each participant was sorted into groups based on their responses to the survey given before or during the study. These groups were as follows:

- All participants (n=50)

- Male participants (n=17)
- Female participants (n=33)
- Participants who workout “Never” (n=1)
- Participants who workout “Infrequently” (n=6)
- Participants who workout “Sometimes” (n=19)
- Participants who workout “Often” (n=24)

For each of these groups, the average of the duration each participant could hold the wall-sit between the baseline and the experimental treatment were gathered, and t-tests were performed on the difference between those two values to determine significance. T-tests were also performed comparing the differences between systolic and diastolic blood pressure between the start and finish of both trials which showed whether the treatment reduced this difference, as the difference between systolic and diastolic blood pressure should increase proportionally to physical exertion (Palatini, 1988). This difference is called the pulse pressure. Lastly t-tests for each group were performed comparing the average final measured heart rate for each group between both trials. Standard deviations were gathered for the differences in each variable.

Statistical outliers were calculated and removed from the differences between those trials. Data that was missing a data point (ex. Final blood pressure for a given participant) resulted in the data point for both trials for a given participant being removed (i.e. for both baseline and experimental trials) when the t-test was performed, in order to ensure the data was paired. T-tests were not performed and standard deviation was not calculated for the “Never” exercise frequency group a due to small sample size (n=1).

<u>Positive Controls</u>

In order to ensure proper functioning of the equipment used in this experiment, positive control tests were conducted on and by 4 out of the 5 investigators of the experiment. The variable measurements were observed to change in the way expected throughout the duration of the wall-sit for each investigator. The average baseline pulse was 81.5 bpm and the final average pulse at the duration of the exercise was 129.3 bpm. The average wall-sit duration was 79.25 seconds the first round. One week later, the average baseline pulse was 82 bpm and the final pulse was 151.8. The final average pulse pressure was 62.5 for the baseline and 47.25 for the experimental trial. The average wall-sit duration in the experimental trial was 81 seconds. These data are summarized in **Table 1**. In both trials, pulse increased as the wall-sit persisted, and this is what was expected. Also, the wall-sit duration average of the second week increased from the first week and the average pulse pressure dropped. Therefore, this proves that the equipment is effective at measuring changes in the physiological variables we are testing, and the variables of the experiment are in-fact measurable.

Negative Controls

The initial resting pulse and blood pressure measurements for each participant, as well as the final measurements at the end of the wall-sit for the first round of testing without the breathing technique, functioned as the negative controls for the experiment. These were measurements without any manipulations or physical exertion performed. Physiological changes from these baseline measurements were observed during the duration of the wall-sits and were compared to the baseline in order to understand how the addition of the breathing techniques to exercise potentially affected participants' pulses and blood pressures. Discrepancies between these periods allowed for the analysis of the impact of the hyper-oxidative breathing technique on the physiological variables measured in this experiment.

RESULTS:

Cumulative results for each metric are shown in **Table 2**. Additional results are detailed below.

Duration

Differences in wall-sit duration between baseline and experimental trials are shown in **Figure 3**. The average duration a participant could maintain a proper wall sit increased by 11.3 seconds (SD=21.4) across all participants, with average increases of 3.6 seconds (SD=38.11) for the female group, 14.6 seconds (SD=19.53) for the male group, 5 seconds for the never exercise group, a decrease of 4 seconds (SD=16.55) for the infrequent exercise group, an increase of 5.59 seconds (SD=13.16) for the sometimes exercise group, and an increase of 11.13 seconds (SD=27.1) for the often exercise group. Of these, the changes for all participants as a whole (p=6.25 x 10^-4), and men (p=0.007) were found to be significant, indicating a correlation between the breathing exercise and an increased wall sit duration. The female, infrequence exercise, sometimes exercise, and often exercise groups has p values of p=0.265, 0.58, 0.099, and 0.056 respectively.

Blood Pressure (BP)

Pulse pressures between baseline and experimental trials are shown in **Figure 4**. The average pulse pressure was 48.48 mmHg (SD=15.74) for the baseline trial and 46.73 mmHg (SD=15.75) for the experimental trial. This yielded an average across each trail of -1.75 (SD=14.14). The t-test conducted gave a p value of p=0.40, indicating this data was insignificant and a correlation cannot be demonstrated between our breathing exercise and pulse pressure from this data. For the subdivided groups, the averages between trials were -1 mmHg (SD=13.05) for the female group, -3.25 mmHg (SD=16.47) for the male group, -15 mmHg for the never exercise group, +2.5 mmHg (SD=15.11) for the infrequent exercise group, -3.35 mmHg (SD=10.90) for the sometimes exercise group, and -2.63 mmHg (SD=15.10) for the often exercise group. The female group had p-value of 0.67, the male group had a p-value of 0.44, the infrequent exercise group had p-value of 0.70, the sometimes exercise group had a p-value of 0.22, and the often exercise group had a p-value of 0.40. The p-values for all groups indicated non-significance for a correlation between the breathing exercise and heart rate.

Heart Rate (Pulse)

Differences between final systolic and diastolic blood pressures between baseline and experimental trials are shown in **Figure 5**. The average heart rate for all participants upon failure of their wall-sit was 126.5 bpm (SD=18.70) for the normal breathing trial and 124.94 bpm (SD=21.26) for the experimental breathing trial. The average difference between these values for the two trials was -2.77 bpm (SD=19.22). The average heart rate for all participants for each time point during the wall sit is shown in **Figure 2**. A two-tailed paired t-test between these trials indicated no significance between the two (p=0.35). For the subdivided groups, the average differences between trials were -0.48 bpm (SD=19.4) for the female group, -5.53 bpm (SD=18.93) for the male group, -3 bpm for the never exercise group, +12.5 bpm (SD=27.7) for the infrequent exercise group, -5.55 bpm (SD=22.78) for the sometimes exercise group, and -2.26 bpm (SD=12.63) for the often exercise group. The female group had p-value of 0.90, the male group had a p-value of 0.28, the infrequent exercise group had p-value of 0.43, the sometimes exercise group had a p-value of 0.32, and the often exercise group had a p-value of 0.44. The p-values for all groups indicated non-significance for a correlation between the breathing exercise and heart rate.

DISCUSSION:

Based upon the p-values calculated for the difference in the wall-sit duration between the baseline trial, without the breathing technique, and the experimental trial conducted one week later with the breathing technique, it can be stated that the hyper-oxidative breathing technique that was adapted from the Wim Hof Method is effective in improving endurance during an anaerobic exercise, such as a wall-sit. These increases in duration were found to be significant for the group of all participants (p=0.000625) and the male group (p=0.007), but were insignificant for the other groups, although the "often" exercising group was nearly significant (p=0.056).

The blood pressure data recorded before and after each wall for each trial indicated a general decrease in the pulse pressures for the breathing exercise trial relative to the baseline trial, with decreases ranging from -15 to -1 mmHg for most groups, with the "sometimes" exercises group showing a mild increase of 2.5 mmHg. These data were not found to be statistically significant, but do appear to display the trend we would expect: that the Wim Hof breathing technique reduces the level of exertion displayed through blood pressure for each wall-sit.

The heart rate data recorded during the initial wall-sits without the breathing exercise plateaus earlier, at 40 seconds, than the normal breathing heart rate, further indicating that Hof's breathing technique is effective in obtaining and maintaining a stable heart rate more quickly (**Figure 2**). However, based on the statistical analysis, this is not statistically significant. This trend observed, however, is an important observation seen in the data, and had the equipment in this experiment been more reliable and if more trials were run with a sample size larger than 50 people, this data could have been statistically significant. We conclude that while our data indicates that the breathing technique did successfully raise the duration an individual could maintain a wall-sit, further studies are needed to determine exactly which physiological changes give rise to this increase.

Study Limitations & Future Directions

While gathering data for the positive controls a manual blood pressure cuff was utilized; the manual blood pressure cuff took longer than expected and was most likely giving inaccurate readings due to the slow time; for this reason an automatic blood pressure cuff was used throughout the remainder of the experiment. Although the automatic blood pressure cuff was effortless, it still resulted in inaccuracies. The cuff would frequently error out and blood pressures had to be re-measured. In the time that passed while taking an additional measurement, the blood pressure value was changing, and in the end, the reading was not the blood pressure directly after the duration of exercise. Inaccurate blood pressure readings also could have resulted from the fact that proper blood pressure techniques were not enforced with every participant (ie. feet flat on the floor, palms facing up, no talking). These proper techniques are stated in The BIOPAC Systems, Inc. Student Manual (ISO 9001: 2008, BIOPAC Systems, Inc.) It was also found that the baseline blood pressure measurements varied amongst participants; this is because individuals' bodies have different set-points for blood pressure. Baroreceptors can reset and, therefore, some people have different "normals." This may have had an effect on the results found for blood pressure. Human error is also a factor that needs to be considered. Human error in taking the blood pressure measurements most likely provided inaccurate readings. The inaccuracy of measurements from the sources listed above may have skewed our data and also resulted in lack of data for a few participants. In the future, utilizing a medically-trained professional with experience in the healthcare field would provide reliable and accurate data.

Similar inaccuracies found in the data can be due to the use of the pulse oximeter/carbon dioxide detector. In many cases, the pulse ox detector had a delayed response resulting in not having a data point for some of the 10-second incremental data points. The inconsistencies from the pulse ox resulted in unreliable data and resulted in lack of data for certain participants. The use of a more reliable and a more advanced pulse oximeter would provide in the future would allow for more consistent data collection.

Some participants did not hold their wall-sit for the maximum possible duration. Unfortunately, with this lack of full-effort to hold the wall-sit until failure, the possible effects of the breathing exercise cannot be fully seen. Every 10 seconds the wall-sit was held, the heart rate was said out loud so that another experimenter could enter the data into a spreadsheet. It was observed that the participants would wait until one of these time increments or check marks and then stop their wall-sit. Therefore, the wall-sits were not being held for as long as possible; muscle fatigue was not fully reached. If the pulse was not said out loud, participants most likely would have held the wall-sits longer, instead of just trying to reach the next 10-second mark.

Nevertheless, some participants may have held the wall-sit longer than expected due to distractions. Conversations were being had during the wall-sits, and this most likely had an effect on the wall-sit duration. A few participants had also announced during the study that their wall-sit time may be affected due to the fact that they had “leg day” the day of or prior, advising the experimenters that their legs were tired from previous leg exercise(s). Additionally, some participants did not have appropriate shoes on for physical activity. If this study were to be repeated, these variables mentioned would need to be controlled for; participants would need to be advised to not talk during the wall sit, not exercise prior to the experiment, and the participants should have been enforced bring shoes suitable for physical activity. Participants who signed up via email were only informed to wear comfortable footwear, but most of the participants signed up the day of for experimentation had no prior knowledge of what the experiment entailed. As well, there is a possibility that some participants may be familiar with our modified breathing technique or Wim Hof’s work. Previous knowledge may affect our results by narrowing the difference between the normal and exercise trials. Participants with previous knowledge have the advantage by having better comprehension on how to utilize a breathing technique thus producing a different result. We should have taken this into account while doing data analysis if we asked the participants about any previous knowledge on breathing techniques in the pre-questionnaire. Other external factors may have also influenced wall-sit duration including, diet, hours of sleep, mental stability, as well as immune system status.

There is a lack of prior research on hyper-oxidative breathing techniques and their effects on physical endurance; this lack of research inhibits the ability to form a foundation of understanding for the effects of hyper-oxidative breathing techniques on physical endurance. This lack of research made it extremely difficult to compare the data found in this experiment to other data. Also, most of the research found on Hof's breathing technique is paired with extreme conditions such as low temperatures, and the participants used in the Hof Method were a specific group consisting of elite athletes. These conditions and participants used by Hof may not translate into this study.

Study implications

Hof's breathing technique activates various physiological responses that will energize and strengthen the body. During the breathing exercise, the participant is inhaling and exhaling in a thorough matter, expanding the alveoli in the lungs at their significant diffusion capacity, thus consuming an excessive amount of oxygen and causing a shift in CO_2 and O_2. By thoroughly breathing in and out, the pH-value in the bloodstream increases from its average pH-value of 7.4. The shift of pH-value allows cells to produce ATP efficiently, while at the same time preventing the production of lactic acid (Hof, 2016). Overall, the shift will result in the optimization of the functions of the body (Hof, 2016).

By practicing Hof's breathing technique, waste materials in the body are easily released and cleansed, while releasing high doses of adrenaline, therefore generating more energy (Hof, 2016). The amount of oxygen that is consumed when we inhale influences the amount of energy that is released into the body. When the data of the baseline trials are compared to the experimental trial (conducted one week later with Hof's breathing technique) the data indicates that the participants were able to hold the wall-sit longer, provided that the breathing technique practiced beforehand generated more energy.

This link found between elevated blood oxygen levels and endurance may have important implications for anyone looking to improve their physical performance. This breathing technique, which has previously been utilized in the past to improve athletic performance under extreme conditions can be translated to improvements of anaerobic endurance for the average individual, such as the participants in this experiment.

Class Relevance

This research further developed our understanding of human physiology as researching Hof's breathing technique and implementing a breathing technique of our own helped us further understand the physiology of the human body. The breathing technique optimizes body functions, generates more energy, and reduces the risk of inflammation and illnesses. The Hof

Method breathing technique puts the body in an active state by producing a ‘fight or flight response’. We learned that the ‘fight or flight response’ is caused by an increase in the concentration of stress hormones, which decreases the production of inflammatory proteins. In this experiment, we also got to see the concept of feedforward regulation, that was taught to us in Physiology 435, put into action. Feedforward regulation is “the aspect of some control systems that allows system to anticipate changes in a regulated variable” (Widmaier *et al*., 2008). As we were explaining the instructions to the participants, a jump in many of their pulses occurred as we told them they were about to do a wall-sit. The increase in heart rate was an anticipation to the changes that were going to occur during the physical activity of the experiment. The hyper-oxidative breathing technique used in this study is also extremely relevant to Physiology 435 because we have recently discussed respiratory physiology in class. The elasticity of the respiratory system organs changes during breathing techniques and this can allow for more exchange of O_2 and CO_2; “due to their great elasticity, lung bubbles generally have significant diffusion capacity. Hence, the so called ‘diffusion surface’ is where the exchange between O_2 and CO_2 takes place. When you breathe calmly, this can stretch up to 70 m^2, yet when you inhale deeply this can expand to 100 m^2” (Hof, 2016). Therefore, the breathing technique used in this study will allow for the stretching and expansion of the diffusion surfaces of lung bubbles, and this will increase O_2 and CO_2 diffusion, which will lead to efficiency while performing physical activities.

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TABLES AND FIGURES

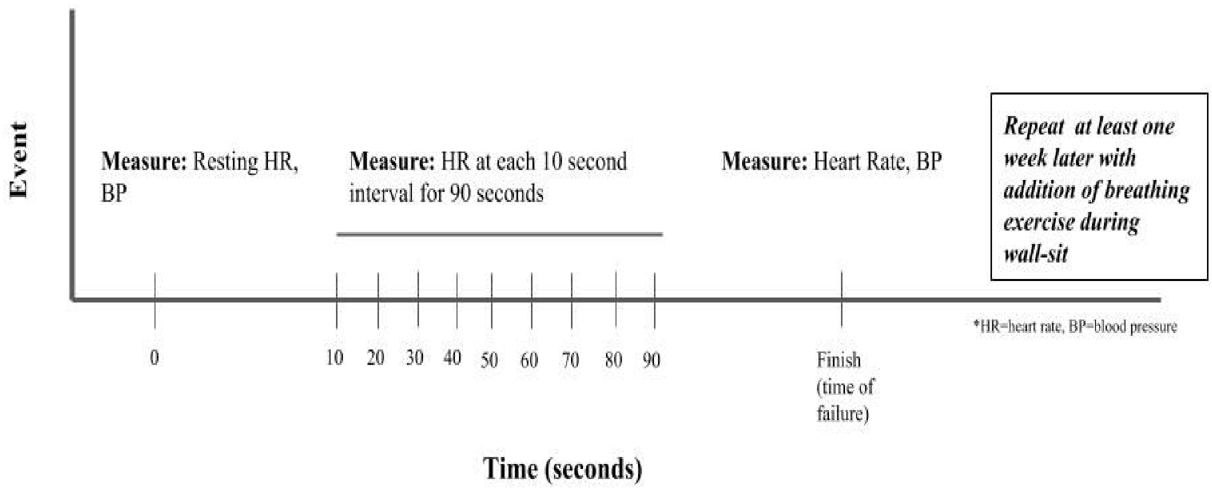

Figure 1: Experimental procedure displayed in linear time. Each trial expected to take 10 minutes or less. Time expected to spend on measurements is however long the pulse-ox and blood pressure cuff take to measure the variables.

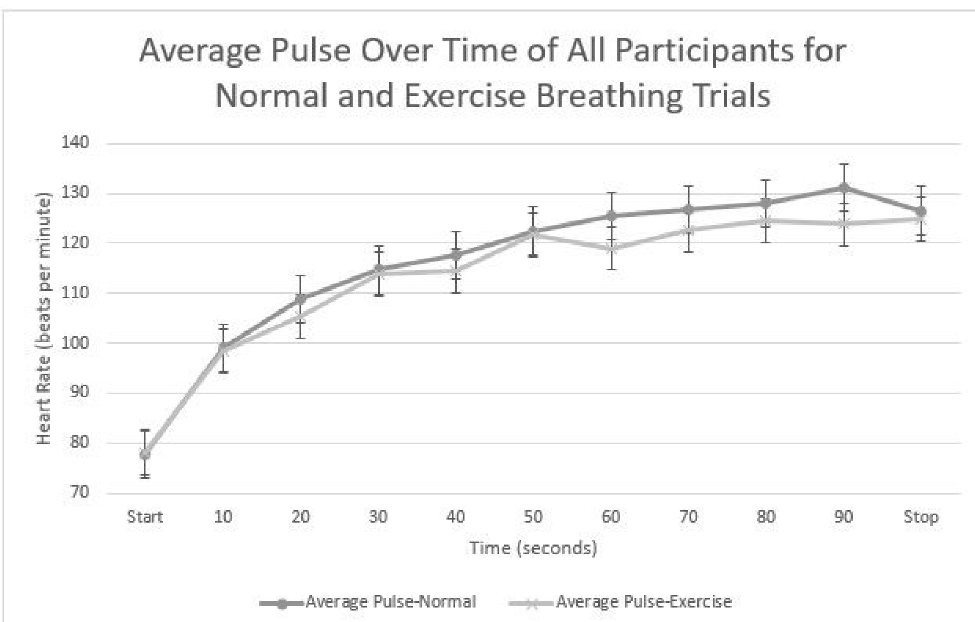

Figure 2: Average heart rate (pulse) over time for all participants for each trial. The data shows an average trend of increasing heart rate as the duration the wall-sit is held. The data also shows the average heart rate for a given duration during the breathing exercise trial was typically lower than the heart rate for the baseline trial. Standard error is shown for the error bars.

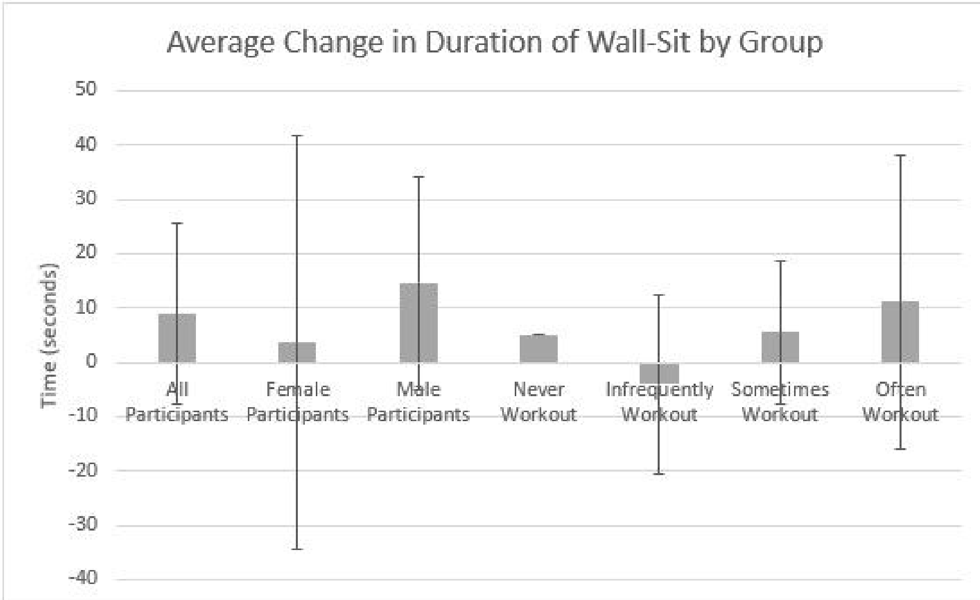

Figure 3: The average change in duration of a wall-sit by group. The graph shows the average amount of the time the wall-sit duration changed from the baseline trial to the experimental trial. Standard deviation is shown as the error bars except for the "Never Workout" category (n=1). The change in duration was found to be significant only for all and male participant groups (p=0.00809 and p=0.007 respectively).

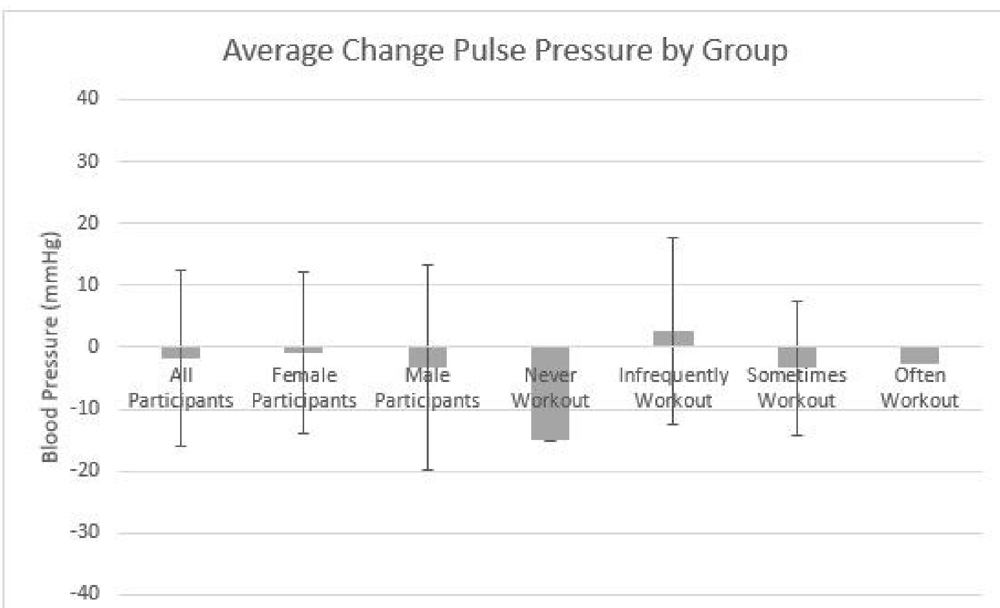

Figure 4: The average change in pulse pressures for each group. The bar graph shows the average change in blood pressure difference between each trial. Standard deviation is shown as the error bars. Differences were not found to be significant for any group between the trials.

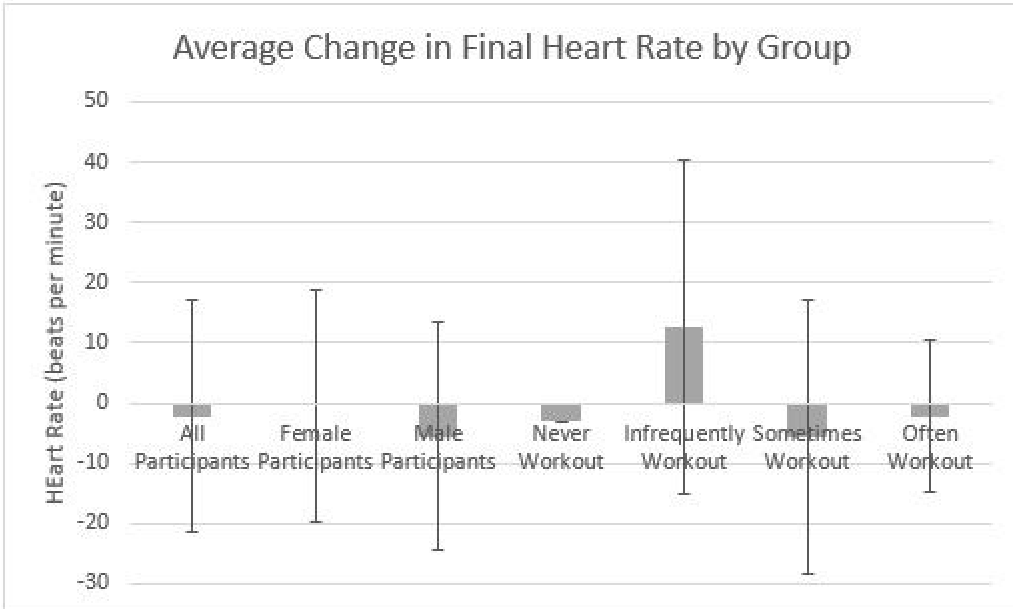

Figure 5: The average change in the heart rate at the completion of the wall-sit by group. The bar graph shows the average change in final heart rate between each trial. Standard deviation is shown as the error bars. Differences were not found to be significant for any group between the trials.

	Starting HR (bpm)	Ending HR (bpm)	Duration (sec)	Final BP difference (mmHg)
Wk 1-Normal Breathing	81.5	129.3	79.25	62.5
Wk 2-Exercise Breathing	82	151.8	81	47.25

Table 1: Positive control data. The table shows the averages of the positive control data gathered from four of the five researchers. Heart rate, wall-sit duration, and difference between systolic and diastolic blood pressure for the final measurement were gathered and analyzed for each trial (week).

Group	Duration	Standard Deviation	Blood Pressure	Standard Deviation	Heart Rate	Standard Deviation
All Participants (n=50)	11.3	21.4	-1.75	14.14	-2.27	19.22
P-Value	0.000625		0.4		0.35	
Female Participants (n=33)	3.6	38.11	-1	13.05	-0.48	19.4
P-Value	0.265		0.67		0.9	
Male Participants (n=17)	14.6	19.53	-3.25	16.47	-5.53	18.93
P-Value	0.007		0.44		0.28	
Workout Never (n=1)	5		-15		-3	
P-Value						
Workout Infrequently (n=6)	-4	16.55	2.5	15.11	12.5	27.7
P-Value	0.58		0.7		0.43	
Workout Sometimes (n=19)	5.59	13.16	-3.35	10.9	-5.55	22.78
P-Value	0.099		0.22		0.32	
Workout Often (n=24)	11.13	27.1	-2.63		-2.26	12.63
P-Value	0.056		0.4		0.44	

Table 2: Experimental results for duration, blood pressure, and heart rate for all groups. Positive values indicate an increase between trials, while negative values indicate a decrease. Two-tailed paired t-tests were performed for each group between trials to determine the effect of the breathing exercise. Only the increases in duration for all participants and male participants were found to be significant ($p<0.05$).