Physiological Rate of Recovery in Relation to Activity Level

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Key Terms: Aerobic, Anaerobic, Autonomic Nervous System, Blood Pressure, Cardiovascular, Exercise, and Respiration.

Abstract

The importance of physical activity is frequently mentioned in regards to improved health and disease prevention; however, how often should one exercise and what type of exercise is most beneficial? Previous studies have established that post exercise recovery rate is indicative of current physical fitness and future health risks. In this study, the effect frequency and type of exercise on post exercise recovery rate are further examined within a healthy college student population. It was hypothesized that individuals who exercised 4-5 times a week would have the most efficient recovery times when measured by percent change in heart rate, blood pressure, and respiratory rate. Participants biked at a moderate pace on a stationary bike for three minutes and their blood pressure, heart rate, and respiratory rate were collected and recorded post exercise. An ANOVA was used to compare the deviation from baseline for each participant. Heart rate and respiratory rate showed a statistically significant change in participants, specifically those who exercise greater than three times a week and participate in both aerobic and anaerobic exercise had the most efficient recovery rate. Though the results of pulse pressure were statistically significant, it was determined that the trends displayed were inconclusive. Due to the significance of our data the null hypothesis was rejected. Overall the study showed that physiologically, physical activity is most beneficial to individuals when a combination of anaerobic and aerobic exercise is integrated into their workout regime for those who exercise more than three days per week.

Introduction

When individuals partake in exercise they may become short of breath, feel their heart rate increase, begin to perspire, or experience myriad of other changes. These physiological responses to exercise and their effect on post exercise recovery rate is a familiar phenomenon that has been extensively explored. Aerobic exercise induces a physiological response during which time the body attempts to maintain homeostasis (Jeffreys, 2005). At the onset of aerobic exercise, there is a combination of sympathetic activation and parasympathetic withdrawal; this can be observed through an increase in heart rate and blood pressure (Pierpont, Stolpman, & Gornick, 2000; Widmaier, Raff, Strang, & Vander, 2016, p. 419). Increased respiratory rate can also be seen at the onset of exercise (Stainsby, Barclay, 1970; Widmaier et al., 2016, p. 419). During aerobic exercise, the body copes with the increased oxygen demand of the muscles and the simultaneous need to eliminate the carbon dioxide byproduct from ATP synthesis (PMC). Post-exercise, the body begins to recover, and return to homeostasis which is defined as a normalization of physiological function and return to homeostasis; meaning that the sympathetic activation decreases and parasympathetic control returns (Jeffreys, 2005).

Past studies have indicated that recovery rate is indicative of vagal tone of the heart (Klein & De Ferrari, 2010; Vivekananthan, Blackstone, Pothier, & Lauer, 2003; Imai et al., 1994). Cardiac vagal tone can be defined as the contribution of the parasympathetic nervous system to cardiac regulation (Laborde, Mosley, & Thayer, 2017). Cardiac vagal tone and heart rate recovery are significant indicators of already present health complications and can also indicate future health risks (Klein & De Ferrari, 2010; Vivekananthan, Blackstone, Pothier, & Lauer, 2003; Imai et al., 1994). Delayed decline in systolic blood pressure post aerobic exercise is also associated with improved cardiac health (McHam, Marwick, Pashkow & Lauer, 1999). The rate at which respiratory rate returns to baseline is related to excess postexercise oxygen which is indicative of overall fitness (Short & Sedlock,1997). Overall, these previous

studies have looked specifically at healthy athletes or non-athletes with chronic health conditions when examining exercise recovery. This study intends to further subdivide the categories previously researched by looking at number of days of exercise per week and types of exercise (aerobic, anaerobic, combination) in relation to recovery rate within a healthy college student population. The purpose of this study is to quantitatively assess and further comprehend how frequency and types of exercise relate to recovery rates within college students. This analysis will help determine which exercise regimen is the most beneficial, with the intent to strive for optimal health outcomes.

It is hypothesized that recovery rate six minutes post exercise cessation, as measured by percent change in heart rate, systolic over diastolic blood pressure, and respiratory rate will be most favorable in subjects that exercise aerobically and anaerobically between 4 and 5 times a week. Both aerobic and anaerobic exercise were selected because studies have shown that both are beneficial to cardiovascular health and improved fitness (Patel et al., 2017). Frequency of exercise was grouped by days in order to acknowledge the delicate balance between sufficient training and adequate recovery time (Bishop, Jones, & Woods, 2008). Rate of recovery will be measured by looking at the percent change in heart rate, blood pressure, and respiratory rate from an established baseline in each subject.

Materials

Heart rate was measured with a Nonin Pulse Oximeter and Carbon Dioxide Detector (Model: 9843, Plymouth, MN) in beats per minute (BPM). The Omron 10 series+ blood pressure monitor measured systolic over diastolic blood pressure in millimeters of Mercury (mmHg). (Model: BP791IT(HEM-7222-ITZ), Omron Healthcare, Inc. Lake Forest, IL). Finally, the respiratory rate was measured with the Biopac Student Lab System (BSL 4 software, MP36) in respirations per minute (RPM). Measurement and analysis of quantitative data was recorded in Google Sheets.

To induce a physiological response to exercise, participants biked for three minutes on a Gold's Gym 390R Cycle Trainer (Model: GGEX61712, Voltage: 220-240 Volts, Frequency: 50 Hz, ICON

Health & Fitness Inc., Logan, UT). The three minutes of biking were recorded on the bike itself, but no data was recorded during the three minutes of exercise.

Methods

Procedure

Participants for this study were selected from the University of Wisconsin-Madison Physiology 435 course in the spring of 2018. A total of 30 participants between the ages of 18-25 were involved in the study. Prior to the study's commencement, participants received an informed consent form describing the nature of the study and extent of the exercise required. Following the completion and collection of the consent form, participants were given a brief questionnaire inquiring about their regular weekly activity levels and any prior health problems or concerns that could alter study results (Figure 1.1). Additionally, participants were asked about their caffeine consumption in the past 24 hours. The completion of the consent form and survey took approximately five minutes. In order to negate the influence of prior food and water intake on the data, the study did not begin until forty minutes into the lab period as this has shown to affect exercise ability in prior studies (Martin, 1976). The questionnaire answers were utilized in the data analysis to further examine the differences in the physiological components of recovery rate between participants.

Prior to the three minutes of biking, participants were instructed to sit on the bike for one minute before baseline physiological measurements were taken with various devices. The respiratory belt transducer was fit to the participants sternum. The pulse oximeter was placed on the participants' index finger of the right hand while the blood pressure cuff was fastened around of the left arm.

Following the initial baseline measurements, participants began exercising at a moderate intensity for a duration of three minutes. In order to keep results and work outputs consistent, participants were instructed to keep their bike speed between 12-16 mph and the resistance at six. Six was used as a moderate resistance level, as the bikes reaches a maximum resistance at 16. This level of exercise was

challenging but not strenuous, as observed in our pilot studies. We chose the biking duration of three minutes due to an observed community standard of this scientific journal in which three minutes is common time. Students with various levels of physical activity were able to uphold these standards. Physiological measurements were recorded by the Biopac Systems, Inc. software as well as visually recorded from the blood pressure cuff and the pulse oximeter machine.

During the exercise, it was the investigator's responsibility to ensure the participant remained within the exercise threshold and also exercised for the complete duration of three minutes (**Figure 1.2)**.

Participants were instructed to reach the mile per hour threshold as quickly as possible and sustain their speed within threshold for the duration of the three minutes of exercise. In an effort to normalize data, participants stayed at the desired activity level for the full duration of the exercise period. Directly following the three minutes of exercise, blood pressure, heart rate, and respiratory rate were collected. For six minutes following exercise, measurements were taken in two minute intervals. Six minutes is sufficient for participants to recover near baseline levels based on the level of physical activity performed (Takahashi, 1998). It was predicted that students with different activity levels would vary in recovery rates. To standardize the data, percent change from baseline will be examined at 6 minute post-exercise, rather than individual recovery time. Six minutes of recovery time was chosen after observing the return to baseline rates in our pilot study.

Data Analysis

Blood pressure was collected a total of six times and recorded in a google sheets form. Further, pulse pressure was calculated by subtracting diastolic blood pressure from systolic blood pressure to normalize the data and account for individual differences in blood pressure. Since pulse pressure is indicative of heart contractility it was deemed as a relevant measurement to obtain. Heart rate and respiration were also measured six times total, four of those times occurring after exercise. The percent change between the first and second recording of all variables was calculated to determine how big of a

change there was between baseline and after three minutes of physical activity. Every two minutes upon completion of the biking exercise, all of the variables were measured and the percent change from baseline was determined, finding the smallest change from baseline after the sixth minute and final measurement. The data was analyzed using ANOVA, which measured the results for variance among the variable means between participants. ANOVA generalized the different variables to t-tests for statistical significance of the physiological data collected between participants. ANOVA was a better fit for our data due to the fact that multiple variables were tested.

Positive Control

Heart rate, pulse pressure, and oxygen respiration were measured and recorded six times throughout the experiment. We calculated the percent change between baseline levels and data collection right after the exercise period. Changes back to baseline levels were monitored for six minutes, at two minutes intervals. Each group member participated in the experiment to ensure the variables would be changing as a positive control. Figures **1.3-1.7** detail the results of the positive control. One group member's heart rate, pulse pressure, and oxygen respiration is detailed over time (**Figure 1.3, 1.5, 1.7**), and the average of the six group members' physiological data with standard deviation **(Figure 1.4, 1.6. 1.8)**. As expected, peak values were seen directly after the exercise period, and then slowly returned to baseline values. Our positive control demonstrated the proficiency of our study design and sensitivity of our study's equipment. Additionally, upon conducting our positive control tests we increased our biking duration from two to three minutes, as we did not witness a substantial physiological change after only two minutes of moderate exercise.

Negative Control

Baseline measurements of heart rate, pulse pressure, and oxygen respiration were taken prior to the subject completing three minutes of biking at zero minutes, and again at one minute to make sure the baseline levels were consistent.

Results

Subject characteristics

A total of 30 subjects participated in this study, however, only 28 participants' results were analyzed, ranging from 20-22 years in age. Because of pre-existing heart heart conditions, two participants were excluded from the data analysis. All participants involved in this study were enrolled in Physiology 435 at the University of Wisconsin-Madison. Each subject was assigned a participant number to ensure that participant information stayed confidential.

Survey Results

Before beginning the study, participants were asked to self-report any pre-existing conditions (including arthritis, heart problems/ disease, asthma, high cholesterol, diabetes, stroke, epilepsy, osteoporosis, dizziness, high or low blood pressure, and any other conditions they were willing to provide), current medications, their current exercise level (describing what type (aerobic only, strength only or a combination), the average intensity of their exercise regime (easy/light, moderate, high intensity/ hard), and how many days they exercise per week. Evidence from **Figure 1.9** showcases the amount that participants exercised per week. Of the 28 participants studied 46.6% of participants exercised infrequently (zero - two days weekly); 32.1% of participants exercised frequently (three to four days per week); and 21.4% of participants exercised very frequently (five to seven days per week). Evidence from **Figure 1.10** indicates that 35.7% of participants reported exercised with cardio training alone, while 14.3% of participants exercised with strength training alone, and 32.1% of participants exercised with a combination of cardio and strength training. A total of 17.9% of participants reported not exercising.

Physiological Data Results

A one-way ANOVA test with a significance level of 0.05 was used to compare the average recovery time of systolic blood pressure, heart rate, and respiratory rate. Recovery time was calculated by subtracting the amount of time it took participants to achieve prior baseline levels measured prior to

beginning of exercise. The one-way ANOVA test was performed 6 times. Heart rate, blood pressure, and respiration were analyzed based on the frequency of exercise a participant completed per week. Additionally, heart rate, blood pressure, and respiration were analyzed based on the type (cardio, strength training or a combination of training) of exercise a participant did per week.

The heart rate recovery data for both the exercise frequency group (**Figure 1.10**) and exercise type group (**Figure 1.11**) showed a significant relationship compared to baseline measurements. The p-value obtained for recovery time in the exercise frequency group was 0.020517 and for recovery time in the exercise type group was 0.047333.

The pulse pressure recovery data for both exercise frequency group and exercise type group showed a significant relationship compared to baseline measurements. The p-value obtained for recovery time in the exercise frequency group was 0.027468 and for recovery time in the exercise type group was 0.009304.

The respiration recovery data for the exercise frequency group showed a significant relationship with a p-value of 0.039494. The respiration recovery data for the exercise type group did not show a significant different among groups differing in exercise type. The p-value obtained for the exercise type group was 0.091564, a statistically insignificant value.

Discussion

The purpose of this study was to analyze post-aerobic exercise activity levels and to determine how varying levels of typical weekly exercise affected variables such as heart rate, blood pressure, and respiration rate. It was hypothesized that individuals who exercised 4-5 times a week would have the most efficient recovery times when measured by percent change in heart rate, blood pressure, and respiratory rate. Because the data was found to be statistically significant the null hypothesis has been rejected. Additionally, it was determined that the study's results were statistically significant.

Upon analysis of exercise frequency in comparison with heart rate, blood pressure, and respiratory rate trends were seen in the data suggesting higher exercise frequency leading to more efficient results of these measurements. The basis for the hypothesis was that individuals who exercised 4-5 times a week would have the best recovery rates was formulated due to knowledge that those who exercised more than that (6-7 times a week) were perhaps subject to the consequences of overtraining. Those who exercised at the highest frequency threshold (6-7 times a week) often do not allow the proper amount of time for muscle recovery and thus hinders their muscular ability to recover. While a positive linear relationship between exercise frequency and recovery rate was expected, very similar results in recovery time between those who exercised at the intermediate frequency (3-5 times a week) and extreme frequency (6-7 times week) were observed.

On average, those who exercised 0-2 times (**Figure 1.13**) per week had a higher heart rate at each of our incremental measurements than those who exercised 3-4 days per week (**Figure 1.13**) and 5-7 days per week (**Figure 1.15**). The increase in heart rate was most significant directly following exercise within individuals who exercise 0-2 times per week recording a substantially higher heart rate in comparison with those who exercise either 3-4 or 5-7 days per week. Higher exercise frequency also resulted in less time required to lower heart rate and an overall lower heart rate after the final measurement. Another trend suggested in the data was that the difference between exercising 3-5 days per week and 5-7 days per week is somewhat negligible, this was seen in the data for heart rate, as the values between the two groups were extremely similar.

The data for pulse pressure points out that those who exercise 5-7 days per week (**Figure 1.16**) had a higher pulse pressure than the other groups (**Figure 1.17**, **1.18**). However, this group displayed the most efficient time to recover to their baseline measurement.

Data for average oxygen respiration was comparable across the three groups (**Figure 1.19, 1.20)**. Unexpectedly, those who exercise 5-7 days per week **(Figure 1.21)** had the highest average respiration following the period of exercise.

It is difficult to draw a physiological conclusion based on the pulse pressure data because of the variability in pulse pressure measurements and meaning. Due to the limitations of the study, the myriad of factors that influence pulse pressure could not be accounted for and were therefore deemphasized. That being said, the data does point towards a specific workout regimen that leads to the most efficient recovery amongst participants. After analysis of the data, participants who exercised 5-7 times a week and incorporated a variability of exercise types seemed to have the best results. Individuals who combined aerobic and strength training cohesively in their weekly workout regimen recovered in the shortest time interval in relation to the other participants who strictly implemented only strength or aerobic exercise.

After data analysis, it was determined that several confounding variables were present in the experiment. Variations in caffeine consumption and the general activity level of the participants were previously screened for. Food consumption too close to the start of the experient potentially inhibited the athletic ability of participants and could have altered their physiological response (Katch & Martin, 1979). Additionally, caffeine acts as a nervous system stimulant, therefore altering baseline and exercise values of heart rate, pulse pressure, and oxygen respiration, so consumption of any type of caffeine before the experiment could have altered our data as well (Daniels, Mole, Shaffrath, & Stebbins, 1998). Other confounding variables include malfunctions in equipment used and the stimulating lab environment in which data was collected. In future studies, testing all lab equipment before running trials could lead to more consistent results. Additionally, using the same equipment throughout data collection could obtain more accurate values throughout the experiment. During data collection, the blood pressure cuff and stationary bike frequently malfunctioned, influencing values for that participant. In terms of the collection environment, a quieter, more controlled setting would be optimal for this type of experiment. Despite

being instructed to be as quiet and still as possible, multiple study participants' respiration and heart rate values were altered due to talking, laughing, or coughing during data collection.

Conclusion

The findings of this study were relevant because they conclude any level of moderate exercise done three times or more a week is indicative of faster recovery rate. In particular, when individuals exercised at least three times per week, recovery to baseline values were obtained faster than those who did not exercise at least three times per week. In fact, any exercise frequency exceeding three times per week had similar recovery rates for heart rate and respiration values. Physiologically, physical activity is most beneficial to individuals when a combination of anaerobic and aerobic exercise is integrated into their workout routines. This leads to the conclusion that as long as an individual exercises at least three times per week alternating between aerobic and anaerobic activities, they are in optimal recovery rate range (Sheps, 2016). In the future, researchers should look into whether we can conclude that recovery rate plateaus due to overtraining. Additionally, maximum effort exerted by participants while studying recovery rate could give insight on their true fitness level and physiological levels of recovery.

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Appendix

Pre-Activity Questionnaire

Participant number: _____

Age: _____

Do you have any of the following conditions (Y/N)

Y	N	Arthritis
Y	N	Heart Problems/Disease
Y	N	Asthma
Y	N	High Cholesterol
Y	N	Diabetes
Y	N	Stroke
Y	N	Epilepsy
Y	N	Osteoporosis
Y	N	Dizziness
Y	N	High or low blood pressure (please circle)
Y	N	Any other conditions you are willing to provide

Please Describe: _____

Are you taking any medications you are willing to list? Y N

If Yes, Please Describe: _____

Are you currently exercising?

Y What type: ☐ Aerobic Only ☐ Strength Only ☐ Combination

Please describe: ☐ Easy/Light ☐ Moderate ☐ High Intensity/Hard

How many times per week: ☐ 1-3 ☐ 4-5 ☐ 6-7

N Have you in the past? ☐ Yes ☐ No

If yes, what type: _____

Figure 1.1 Pre-activity questionnaire gathering information about pertinent medical history and activity levels for each subject.

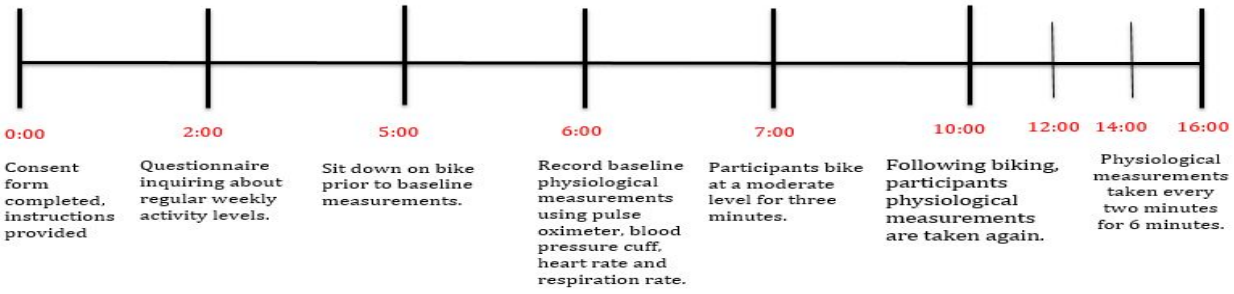

Figure 1.2 Timeline illustrating the breakdown of what occurred during the experiment for each participant.

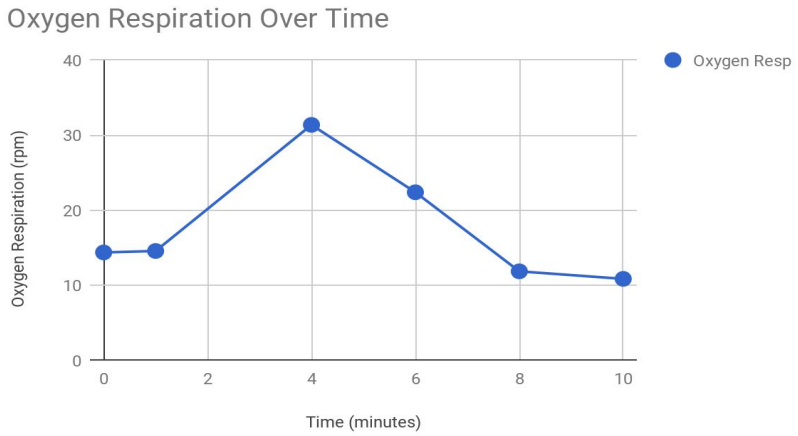

Figure 1.3 Pilot study data (Control Participant 1) showing the change in breaths per minute over the duration of the experiment.

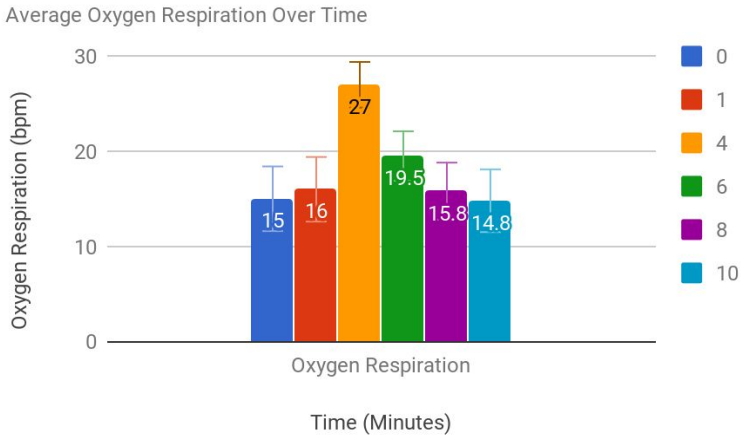

Figure 1.4 Pilot study data (average of all 6 Control Participants with each Standard Deviation) showing the average number of respirations for each time measurement.

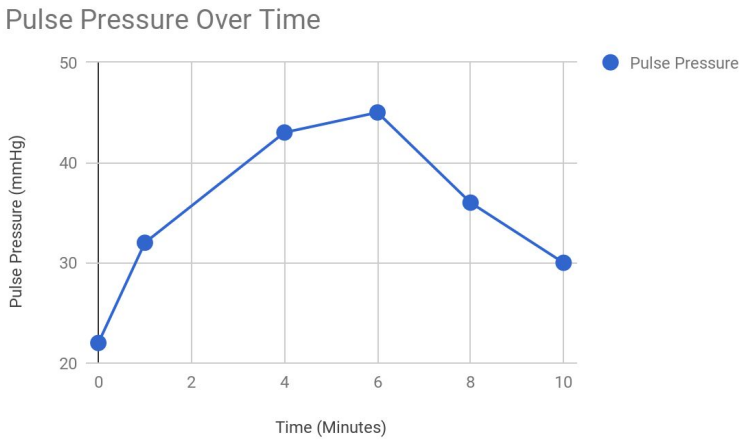

Figure 1.5 Pilot study data showing the change in pulse pressure over the duration of the experiment (Control Participant 1).

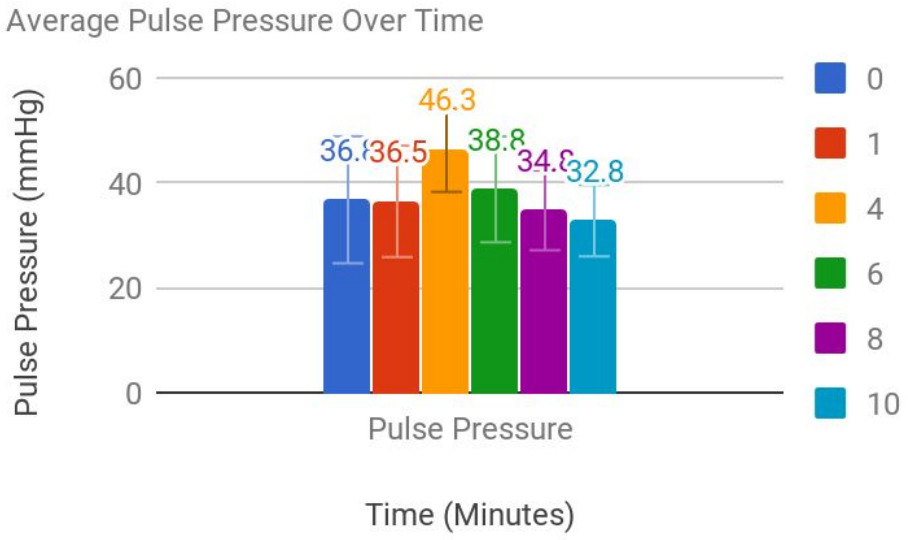

Figure 1.6 Pilot study data showing the average pulse pressure and Standard Deviation for each of the 6 Control Participants over the duration of the experiment.

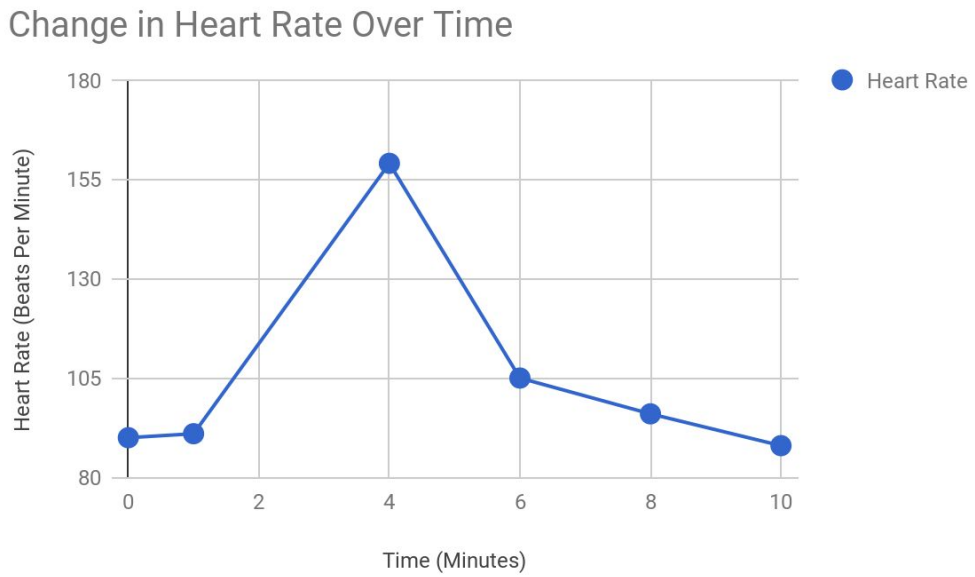

Figure 1.7 Pilot study data showing the change in heart rate over the duration of the experiment (Control Participant 1).

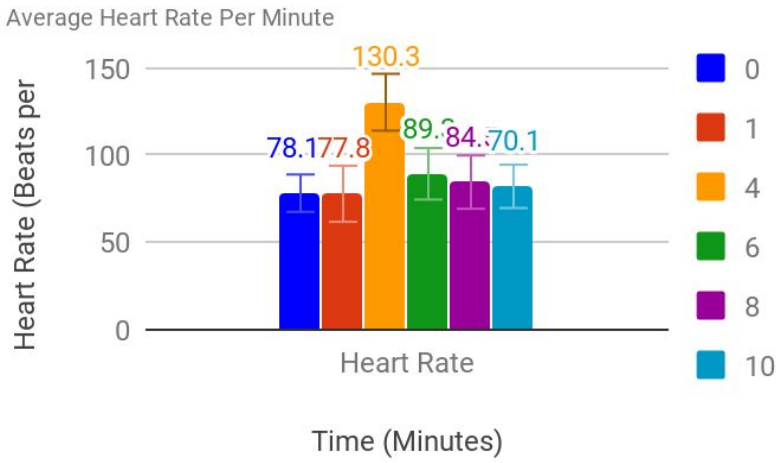

Figure 1.8 Pilot study data showing the average heart rate for all 6 Control Participants and the Standard Deviation.

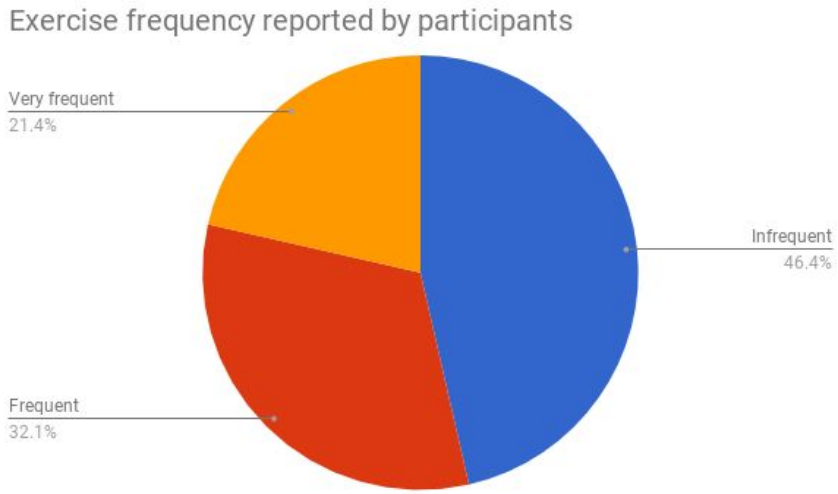

Figure 1.9 Exercise Frequency reported by participants in the study.

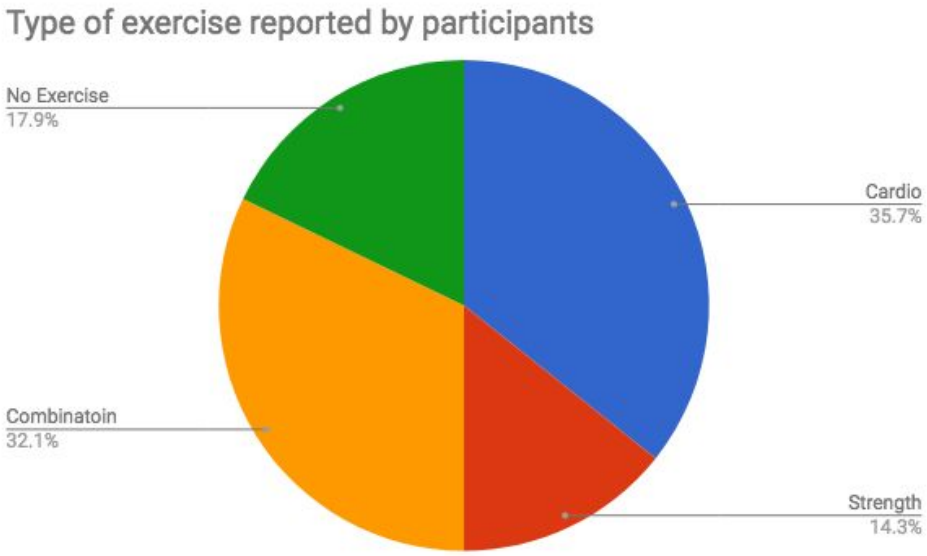

Figure 1.10 The different types of physical activity that participants report how they spend their time exercising.

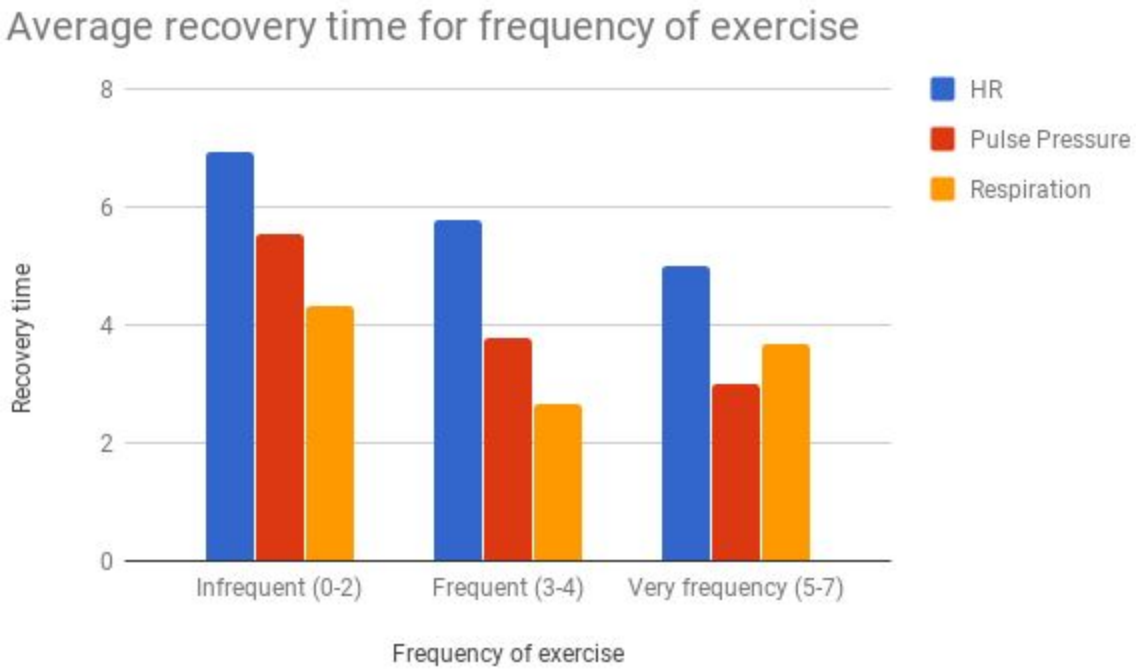

Figure 1.11 Average recovery time for frequency of exercise analyzed using ANOVA.

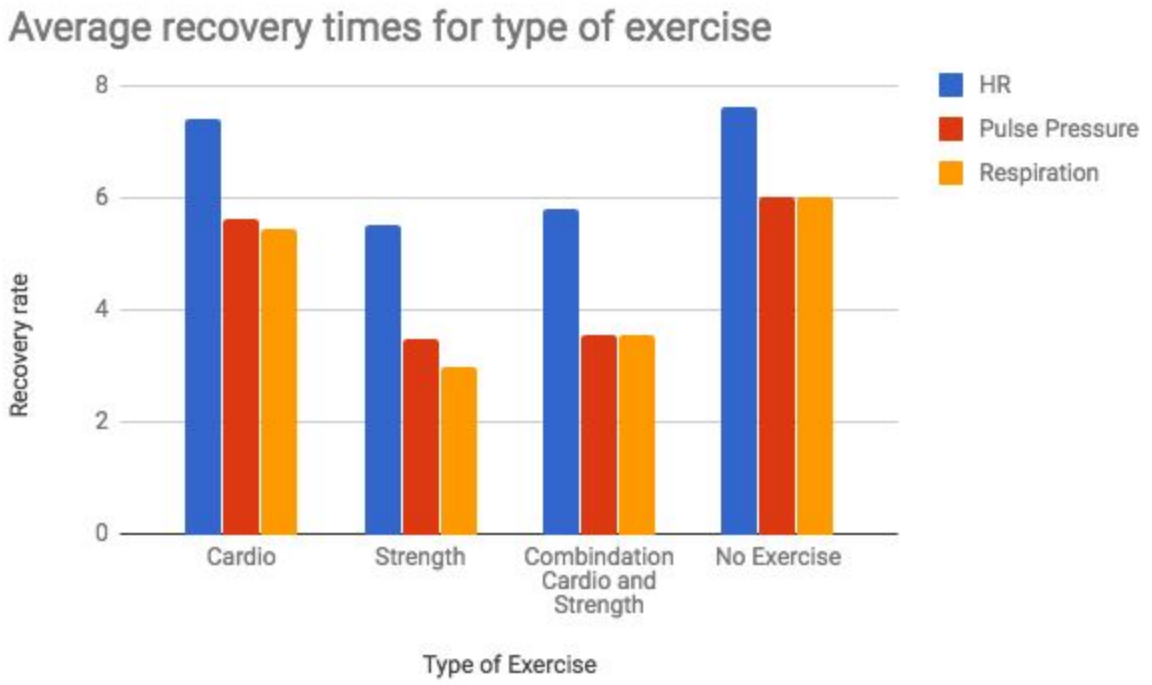

Figure 1.12 Average recovery times for each type of exercise that was analyzed using ANOVA.

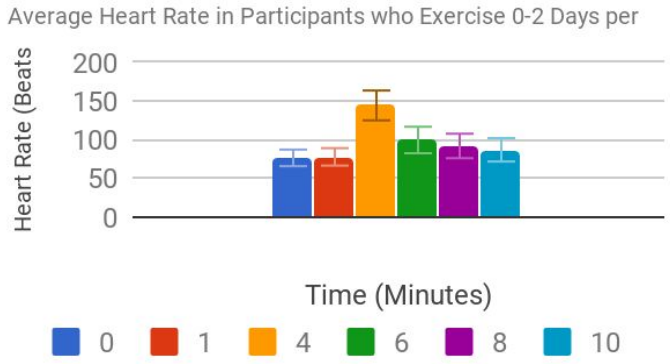

Figure 1.13 Average heart rate values for participants who indicated they exercised 0-2 days per week. Standard deviation is included for each individual measurement.

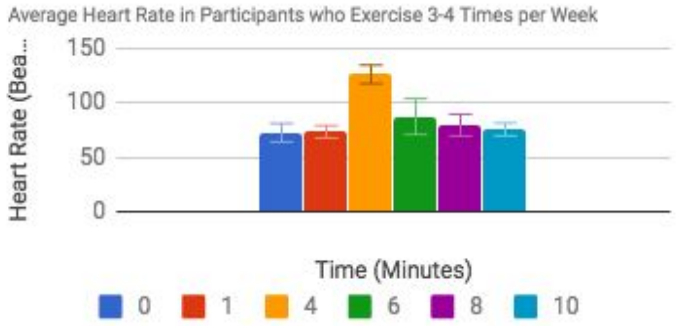

Figure 1.14 Average heart rate values for participants who indicated they exercised 3-4 days per week. Standard deviation is included for each individual measurement.

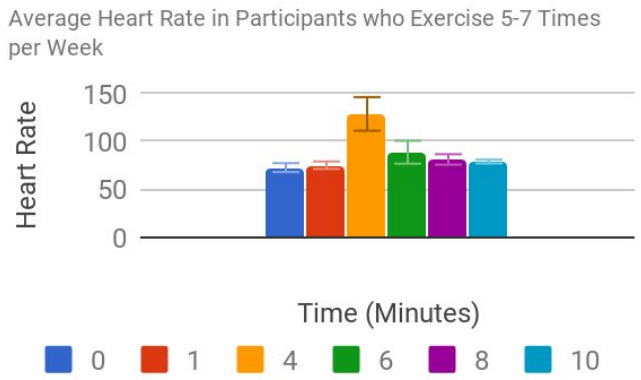

Figure 1.15 Average heart rate values for participants who exercise 5-7 days per week. Standard deviation for each individual measurement is included.

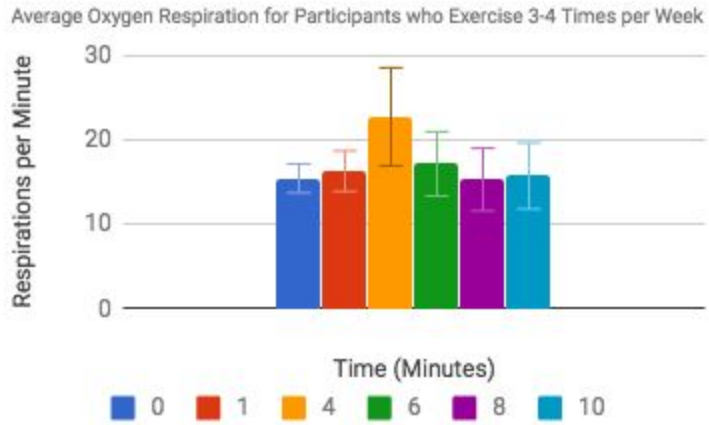

Figure 1.16 Average pulse pressure values for participants who exercise 5-7 days per week. Standard deviation for each individual measurement is included.

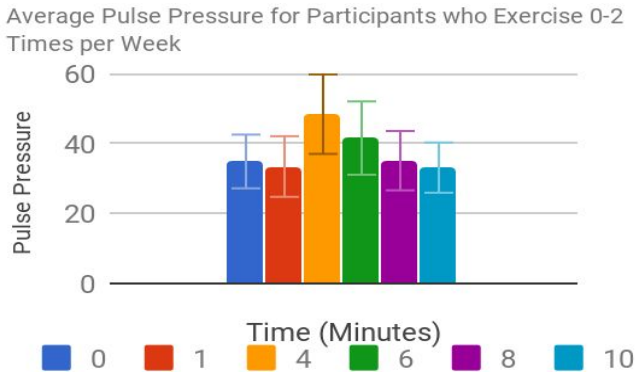

Figure 1.17 Average pulse pressure values for participants who indicated they exercised 0-2 days per week. Standard deviation is included for each individual measurement.

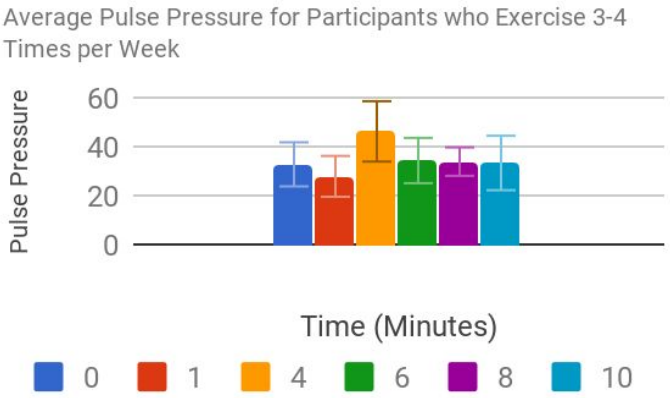

Figure 1.18 Average pulse pressure values for participants who exercise 3-4 days per week. Standard deviation is included for each individual measurement.

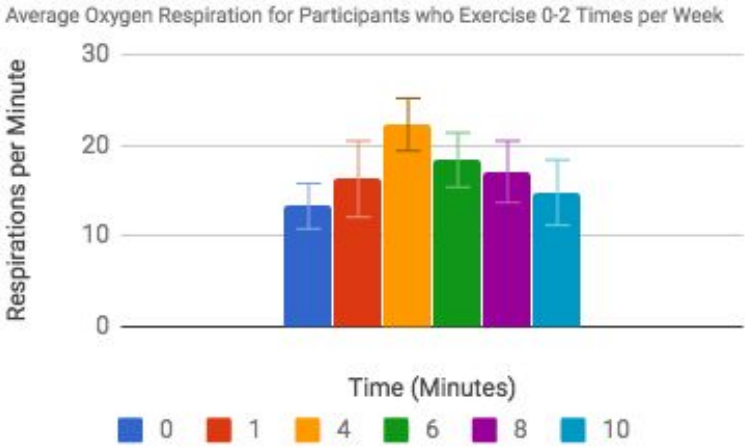

Figure 1.19 Average oxygen respiration values for participants who indicated they exercised 0-2 days per week. Standard deviation is included for each individual measurement.

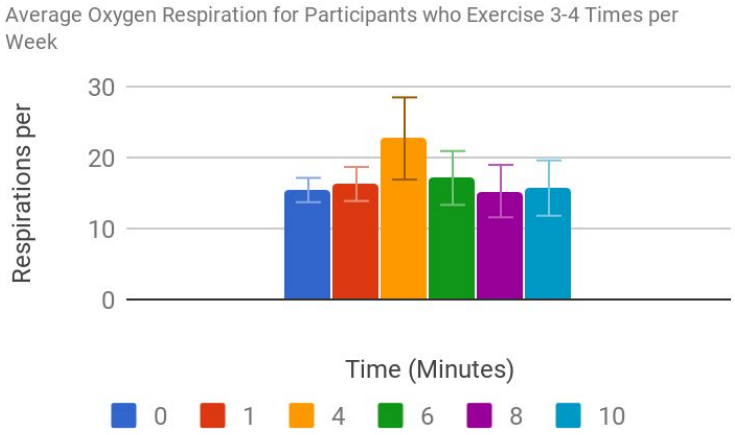

Figure 1.20 Average oxygen respiration values for participants who exercise 3-4 days per week. Standard deviation for each individual measurement is included.

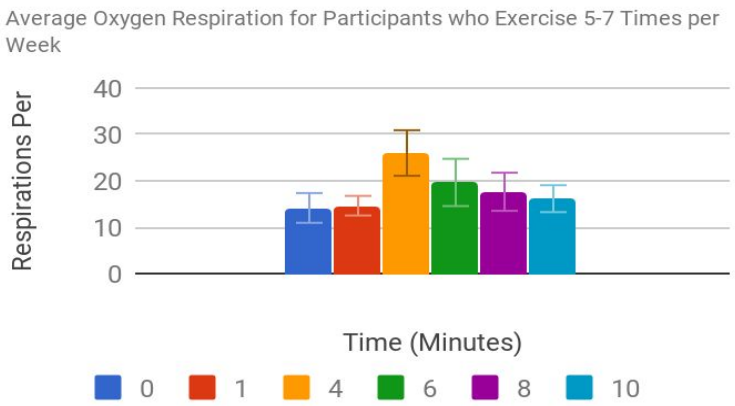

Figure 1.21 Average oxygen respiration for participants who exercise 5-7 times per week. Standard deviation for each individual measurement is included.