The Effects of Exercise on Reaction Time

Lab 601, Group 1

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Abstract

Past research has shown that an individual's reaction time can be a valid indicator of the central nervous system's ability to receive and synchronize movement expressed through the peripheral nervous system. This cognitive-motor connection is a key player in many aspects of daily living including, but not limited to: making quick decisions in dangerous situations, athletic abilities, prevention from injury, and sustained autonomy with aging. Because exercise is known to increase blood flow and oxygen to the skeletal muscles and the brain, it was inferred that exercise would also affect an individual's reaction time, since both skeletal muscle and the brain are separately associated with reaction time. To determine this, thirty subjects gave baseline blood pressure, heart rate, and simple reaction time measurements. They then participated in an acute-intense exercise, defined as a doubled heart rate maintained for five minutes. Post-exercise blood pressure, heart rate, and simple reaction time measurements were taken and the data was analyzed using a Wilcox's paired T-Test. The results concluded that acute-intense exercise decreased reaction time, meaning there was significant improvement in reaction time abilities. This data suggests that exercise is beneficial to people in their daily lives because it influences reaction time abilities.

Key words: acute-intense exercise, auditory, blood pressure, focused, heart rate, reaction time, and stimulus.

Introduction

For years, people have studied exercise and the differing effects it has on the human body. Exercise has been known to control weight management, improve mood, motor function, and cognitive processing (Mayo Clinic, 2014). From a cellular perspective, when an individual engages in intense physical activity, the skeletal muscles utilized consume an increased amount of ATP (energy). The elevated demand of aerobic respiration leads in an increase in the body's requirement for oxygen, therefore explaining the increase in respiration and heart rate effect of exercise. These responses allow more oxygenated blood to flow to the many muscles of the body and help to maintain adequate motor functioning. Increased blood flow also makes its way to the brain and has been shown to have similar benefits for cognitive processing (Poels *et al.*, 2008). Several papers have been published focusing on the study of these post-exercise cognitive improvements by testing short-term and working memory; however, there have been fewer studies that have looked at the connection between cognitive and motor functions (Brisswalter *et al.*,1997 and Keen *et al.*, 1993).

The studies that have looked at this "connection," have tested the reaction times of subjects following different types of physical activities. Reaction time, defined as being the time between the application of a stimulus and the beginning of an organism's response to it, has been shown to be a valid indicator of the central nervous system's ability to receive and synchronize movement expressed through the peripheral nervous system (Garg *et al.*, 2013). Current studies that have explored this have contradicting results due to an array of inconsistent methods and strategies of measuring reaction time. To illustrate, reaction time experiments can be classified into three main categories. First, a simple reaction time test utilizes one stimulus and measures one response. Next, a recognition reaction time test employs symbols to either ignore ('distracters') or react to with only one correct stimulus, thus eliciting one correct response. Lastly, the choice reaction time test: there are multiple stimuli and multiple responses and the reaction must correspond to the correct stimulus. (Kosinski, 2013)

After thorough research, it was decided to conduct an experiment in which subjects were tested with a simple reaction time model immediately after participating in acute-intense physical activity. Based on the physiology that heart rate is directly proportional to exercise intensity, "acute-intense exercise" was defined as having subjects pedal on a stationary bicycle (set at a specific resistance) and increasing their heart rate to double that of the participant's resting heart rate. Simple reaction time model was used because the purpose of the study was to investigate a biological response to one stimulus, while limiting the amount influence from higher order cognitive processes (e.g. recognition and stimuli discrimination) that are required by the other reaction time assessments. Additionally, an auditory stimulus was used because previous research has confirmed that it is an accurate measure of simple reaction time and more efficient than the use of visual stimuli. (Galton, 1899; Woodworth and Schlosberg, 1954; Fieandt *et al.*, 1956; Welford, 1980; Brebner and Welford, 1980). Therefore, this study investigated the question: will simple auditory reaction times decrease following acute-intense exercise?

In the study, heart rate, blood pressure, and reaction time were measured before and after a participant performed acute-intense exercise. Prior to exercise, participant's heart rate, blood pressure, and reaction time were taken via PulseOx Monitor, Sphygmomanometer, and Reaction Timer, respectively, and were measured to have baseline statistics. These baseline measurements served as controls for the experiment and were compared to values taken after exercising. The duration of the acute-intense exercise was evaluated by doubling the heart rate and then having each subject maintain the same exercise intensity for five minutes. The hypothesis for this study is that participants' reaction times will decrease following acute-intense exercise; therefore, supporting the idea that exercise is beneficial and can improve an individual’s simple reaction time abilities.

Materials

The measurements taken required the use of many devices: The Pulse Ox (heart rate monitor), which is a finger clip sensor from Nonin Medical Inc., model 9843; An Adult Aneroid Sphygmomanometer (blood pressure cuff) from GF Health Products, Inc.; All the materials necessary to record the reaction time, including the BIOPAC Hand Switch (SS10L), BIOPAC Headphones (OUT1 or OUT1A), Biopac Student Lab System: BSL 4 software, MP36 or MP 35 hardware, Biopac Student Manual, and a Computer System (Windows 7, Vista, XP, Mac OS X 10.5-10.7). Lastly, a stationary bike was used as the mode exercise.

Methods

Subjects and Survey

A total of 30 people were tested for this experiment, seventeen females and thirteen males between the ages of 19-22. In order to gain individual baseline fitness levels, each participant was asked questions based on his/her daily exercise routine; (1) Do you exercise regularly? (2) How much do you exercise a week? (3) How long is the duration of each workout? and (4) What type of exercise do you do? (Cardio vs. Weight Training) This was noted to help explain trends among participants who do exercise regularly and those you do not.

Measurements

First, the participant’s baseline heart rate and blood pressure were measured using the Pulse Ox (heart rate monitor) and aneroid sphygmomanometer, respectfully. The heart rate monitor was placed on the participant’s non-dominant index finger.

Headphones were then placed on the participant so they could hear and respond to the auditory reaction time stimulus. Additionally, a hand switch that was connected to the Biopac program on the computer was placed in the participant’s dominant hand. The Biopac program recorded each individual’s time between the application of an auditory stimulus and his/her response to it via the hand switch. Biopac Systems Inc. also provided a Student Lab Manual to explain the procedures to correctly perform the reaction time test. When this program was started, the subject heard several beeps administered randomly over the course of seventy seconds. The subject was then required to push the hand switch every time a beep was heard. The hand switch was positioned in their dominant hand to eliminate bias. The heart rate monitor, sphygmomanometer, and reaction timer remained attached to the participant during the duration of the experiment in order to prevent delayed test results. A calibration step, involving one random beep that the subject needed to react to, occurred before each reaction time recording (pre and post exercise). This allowed recordings to be more accurate and also taught the participants how to use the hand switch to eliminate deviations in reaction times due to “user error.” All subjects were tested in the same area to ensure consistent background noise level throughout testing and therefore kept the environment relatively constant for all individuals.

Once all the initial measurements were taken, the participant began to exercise on the stationary bike until the heart rate monitor showed double the baseline heart rate. After this was reached, the participant maintained exercise for five minutes. The heart rate monitor was kept on the participant’s finger throughout the duration of exercise to ensure that the participant kept their heart rate at least doubled from that of their resting.

Immediately following the five minutes of exercise, the ending heart rate was recorded, blood pressure was measured, and the reaction time was retested. This whole process took about 13 minutes per subject (Figure 1).

Controls

The whole process was measured on two of the research subjects, one male and one female, to make sure there was a positive control with the tests. The positive controls confirmed that the procedure was competent in observing the effect that exercise did induce a change in the measurable variables. In addition, it also confirmed that experimenters knew how to use all the equipment so that accurate results were concluded. The positive control experiment was conducted on the subjects and found that there was a change from their pre-workout measurements (baseline) to their post-workout. The female subject’s resting heart rate, blood pressure, and reaction time were 75, 108/70, and 0.213 seconds, respectfully. The male subject’s resting heart rate, blood pressure, and reaction time were 70, 130, and .224 seconds, respectfully. The post-exercise heart rate, blood pressure, and reaction time were 169, 128/70, and 0.169 seconds, respectfully for the female subject and 145, 140, 0.216 for the male subject. Then the subjects were measured ten minutes after exercise to make sure that blood pressure and heart rate returned to baseline, thus proving that exercise induced a change. These changes in numbers concluded that there was an accurate positive control (Figure 2).

Two problems were encountered while setting up and conducting the experiment. First was the definition of exercise and deciding which type of exercise would be good for this experiment. A stationary bike was utilized because it was a consistent way for the subject to exercise for a set amount of time. The second problem encountered was the definition of heart rate, how it should be measured, and what monitor to use. After research of many different articles that employed doubling the subject's heart rate or a percentage of the maximum heart rate, it was decided to double the heart rate because it could easily be controlled and monitored with the Pulse Ox.

Analysis

For interpreting the measurements, the statistical analysis program R was used to perform a Wilcox paired T-test, comparing pre and post exercise measurements, and to make a box plot that showed any outliers in the data.

Results

From the experiment, it is concluded that increasing a participant's heart rate and blood pressure through exercise led to a significant decrease in reaction time. This significance is evident in the p-value of 0.0002575, which was obtained through the Wilcox paired T-test. The Wilcox paired T-test was chosen because it was the most appropriate test in evaluating two samples that are "correlated" over repeated measurements (Social Science Statistics, 2014).

Figure 3 shows reaction times that were tested prior to exercise, ranging from 0.169 seconds to 0.388 seconds. After approximately seven minutes of exercise (two minutes to increase heart rate and five minutes maintained at elevated heart rate), reaction times ranged from 0.168 seconds to 0.279 seconds. These results indicated a decrease in reaction time after acute exercise took place.

In order to assess whether exercise did increase participant's heart rate and blood pressure, both variables before and after the occurrence of exercise took place were measured, which can be observed in Figure 4 and 5. An average heart rate of 75.77 beats per minute (bpm) before exercise was elevated to an average of 142.76 bpm, taken immediately after completion of acute exercise (Figure 9). This was proven to be a significant increase between resting heart rate and post exercise heart rate (p-value= 2.951×100^{-11}). Similarly, the average systolic blood pressure of 122.33 mmHg was increased to an average of 141.6 mmHg with exercise (Figure 10). This significance can be observed in the p-value of 2.431×10^{-6}. Both p-values for systolic blood pressure and heart rate were obtained through the Wilcox Test.

The results also indicated that both increased heart rate and blood pressure during exercise independently had an impact on decreasing reaction time. Figure 6 shows a linear relationship with a slope of 0.0009 between increased in heart rate and a decrease in reaction time after exercise occurred. Similarly, Figure 7 shows a linear relationship with a slope of 0.001 between increased systolic blood pressure and decreased reaction time after exercise occurred.

Discussion

The results concluded a p-value of 0.0002575, which is very significant. This value shows that reaction time did decrease with acute exercise, which proved the hypothesis correct. The hypothesis was as such because of the role that the peripheral nervous system played a part in exercise. With exercise, the sympathetic nervous system is activated and there is an increase in blood pressure and heart rate. In order to allow the body to maintain exercise at these elevated heart rate and blood pressure levels, epinephrine was also released. By binding to beta-2 receptors on the vessels, epinephrine causes dilation to occur and a decreased total peripheral resistance. Both of these changes allowed for an increase blood flow to all areas of the body. The study by Poels *et al*., 2008, concluded that more blood flow allowed the brain to have better cognitive functioning. As shown in Figure 4, blood pressure has increased with acute exercise and can therefore be concluded that exercise helped the brain react to stimuli faster.

Within the experiment, one of the thirty participants was considered an outlier because their resting reaction time was statistically greater than the other twenty nine subjects (Figure 11). It can be suggested that the exercise and equipment distracted this individual instead of being more focused, or there was a problem hearing the reaction time stimulus. If the outlier was taken out of the data collected, there would be more conclusive data and an even more significant p-value.

Other sources of error within the experiment could be attributed to some participants watching the reaction time stimulus on the computer, which increased their anticipation of the auditory stimulus. This heightened anticipation could impact the experiment by having faulty data numbers because the participant should have had a lower reaction time if they had not watched the screen. Also, participants that had outlier results indicated that the stationary bike seat proved to be difficult because they kept falling off. This could have distracted them and made them not exert themselves as fully as they could have. Thirdly, the experiment was conducted in an area with a lot of distractions that did not have control over instead of in a controlled environment. If the experiment was in a controlled room, it could have aided in the participant being more focused and reacting to the auditory stimulus faster thus reducing reaction time. Lastly, while not a direct source of error, the fact that only one reading per subject was taken may have been limiting to the study, since additional readings were not present to confirm the conclusions. Future studies could include multiple readings with each subject in order to draw more concrete conclusions.

On Figures 6 and 7, the R^2 values were 0.24758 and 0.16155, respectfully, which is unacceptable. However, this does not account for the fact that each individual has a different resting and post exercise heart rate and blood pressure, which in turn affects the amount each variable can increase in value in response to acute exercise. Also, the graphs are not comparing before and after exercise (as seen in Figure 4 and 5); both graphs are strictly showing the relationships between post-exercise auditory reaction time and heart rate, and post-exercise auditory reaction time and blood pressure.

In addition to each participant performing acute exercise and measuring individual auditory reaction time, each participant was asked survey questions about his or her daily exercise routine. They were each questioned: how many days a week they exercise, how long these workouts were, and what type of exercise they performed (cardio, weight training, or both).

After strictly analyzing the data collected on reaction time before and after exercise, it was decided to further investigate the participants' survey answers. Correlations between pre-exercise and post-exercise reaction time were identified and the amount of daily exercise of the participants was reported. Because most subjects reported doing a combination of both cardio and weight training for an average of an hour a day, thirty subjects were separated into two different groups based on the number of days they exercised per week. Therefore, individuals that reported exercising 3-7 days a week were categorized as the "moderate exercise group," while individuals that exercise 0-2 days a week were put into the "little to no exercise group." After separating the participants into the established groups, the individual changes in pre-exercise and post-exercise reaction times were examined and a correlation was observed. It was found that those subjects in the "little to no exercise group" had, on average, a greater difference between the two reaction times in overall reaction times compared to those in the "moderate exercise group (Figure 8). Because the focus of the experiment was not directed towards reaction times and an individual's level of physical fitness, these preliminary results can only be viewed as an observation. With that said, the strong correlation seen in Figure 8 suggested that there is an opportunity for a future experiment.

The importance of this experiment can be related to many individuals in improving their everyday life and their health, specifically related to athletes and senior citizens. For athletes, there is an emphasis on improving their skills, like becoming faster and more instinctive than the opponent team. This experiment concluded that, through acute-intense exercise, athletes between the ages of 19-22 years old would continue to improve their reaction time, making them better equipped to participate in a fast paced environment that many sports encompass. As for senior citizens, since this experiment draws conclusions for 19-22 year olds, incorporating acute-intense exercise in their daily schedule starting in their early twenties, could have significant long-term health benefits later in life. By establishing an exercise regimen early in life and maintaining it, senior citizens would ultimately improve their reaction time, which could aid in balance and coordination. This in turn could help reduce or eliminate falling incidents and improve their overall health and cognitive functioning.

Since the experiment was conducted on participants ranging from 19-22 years old, educated guesses on individuals outside this age range can be made on why they should exercise and the impact exercise has on their health. As mentioned above, establishing a workout routine early in life could help improve overall health later in life. It can also improve one's resting heart rate and, therefore, live a longer life. Even though exercise increases heart rate and makes the heart work harder to pump blood to the body, overtime the resting heart rate will decrease. This implies the heart will not have to work as hard when resting, suggesting that exercise improves overall health.

Figure 1

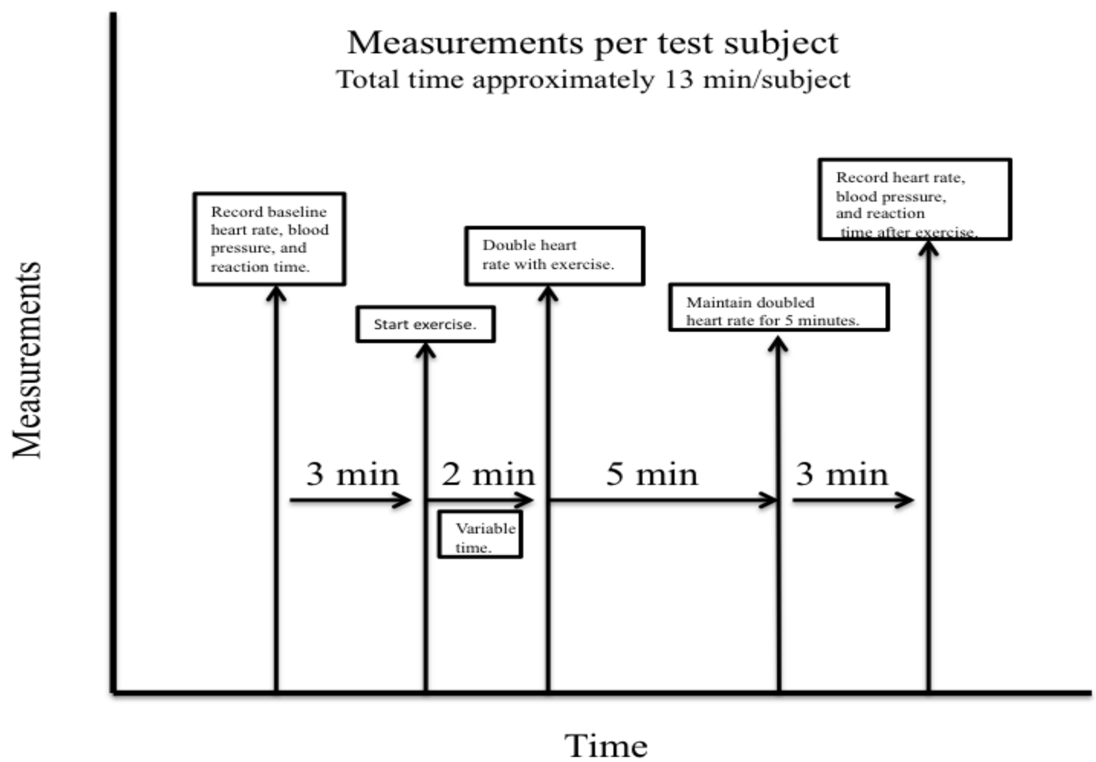

Figure 1: Indicates the approximate time it takes per subject from start to end of experiment.

Figure 2
Positive Control

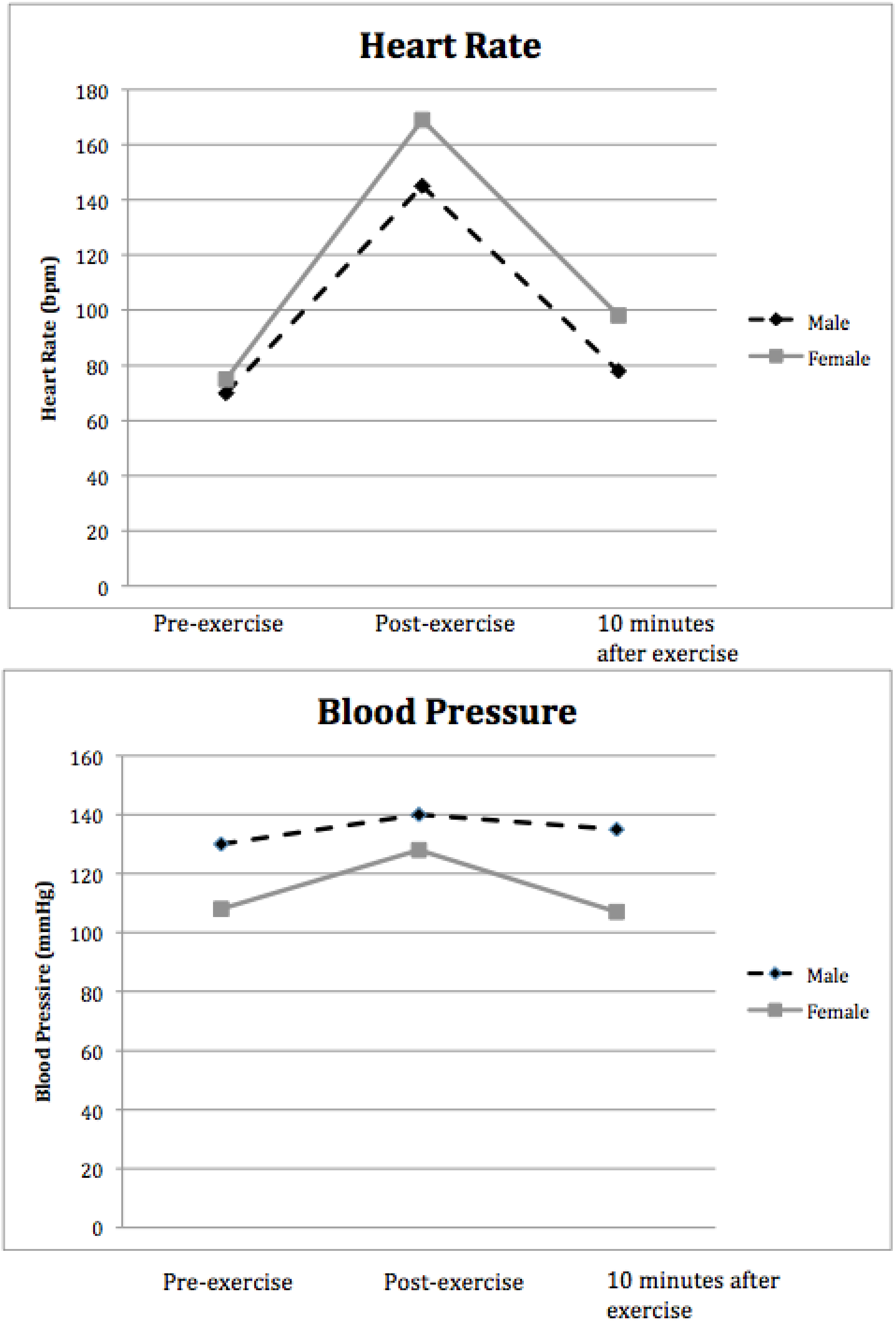

Figure 2: Indicates that both heart rate and blood pressure increase with exercise and return to normal after exercise for both males and females.

Figure 3

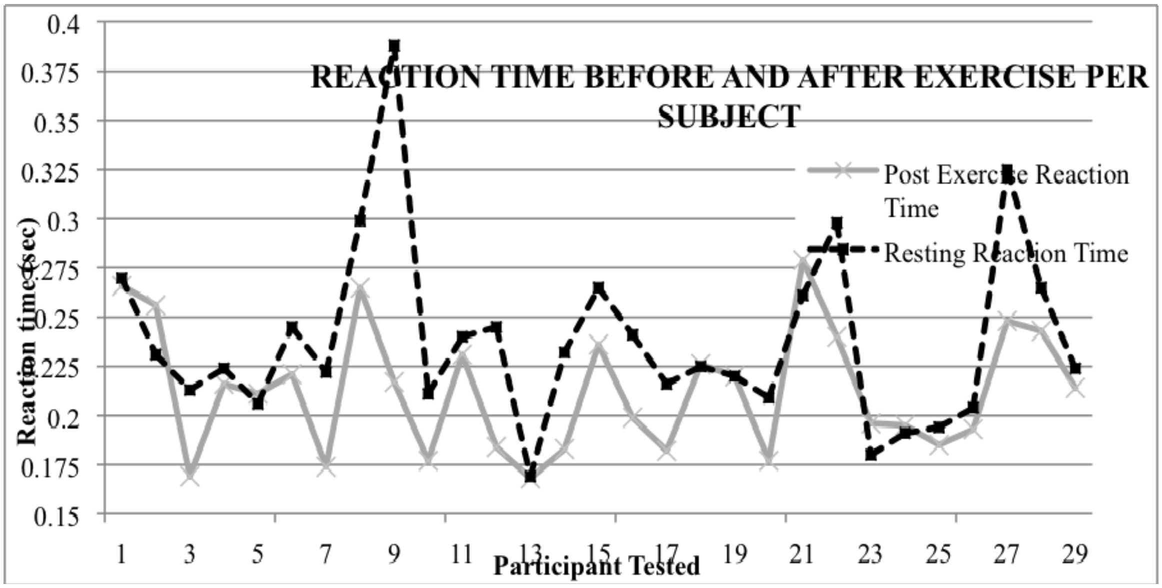

Figure 3: Immediate change in resting auditory reaction time and post acute exercise auditory reaction time for each individual subject, N=30.

Figure 4

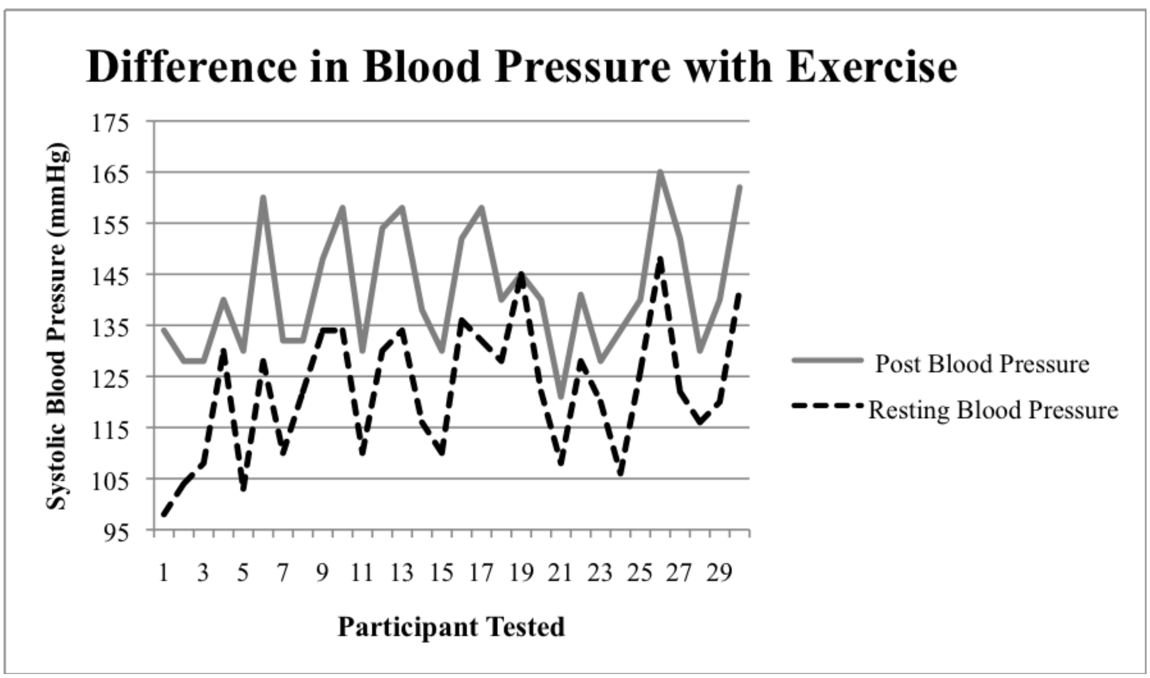

Figure 4: Immediate change in resting systolic blood pressure and post acute exercise systolic blood pressure for each individual subject. Post systolic blood pressure taken within one minute of completion of acute exercise, N=30.

Figure 5

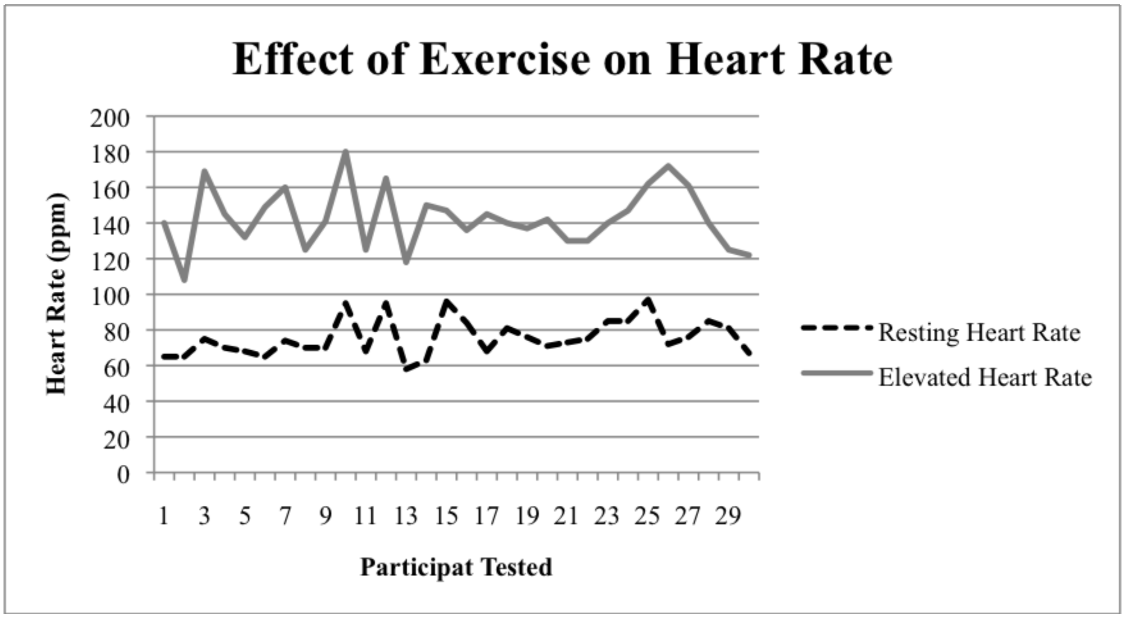

Figure 5: Immediate change in resting heart rate and post acute exercise heart rate for each individual subject. Post systolic blood pressure taken within one minute of completion of acute exercise, N=30.

Figure 6

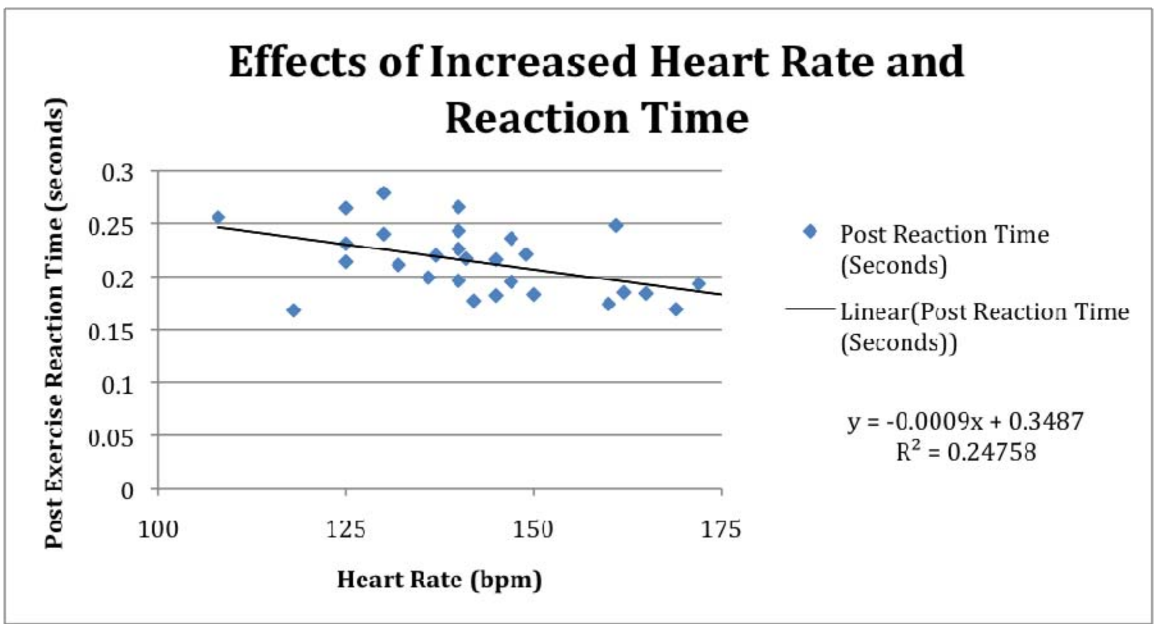

Figure 6: Post acute exercise auditory reaction time as a function of heart rate, N=30.

Figure 7

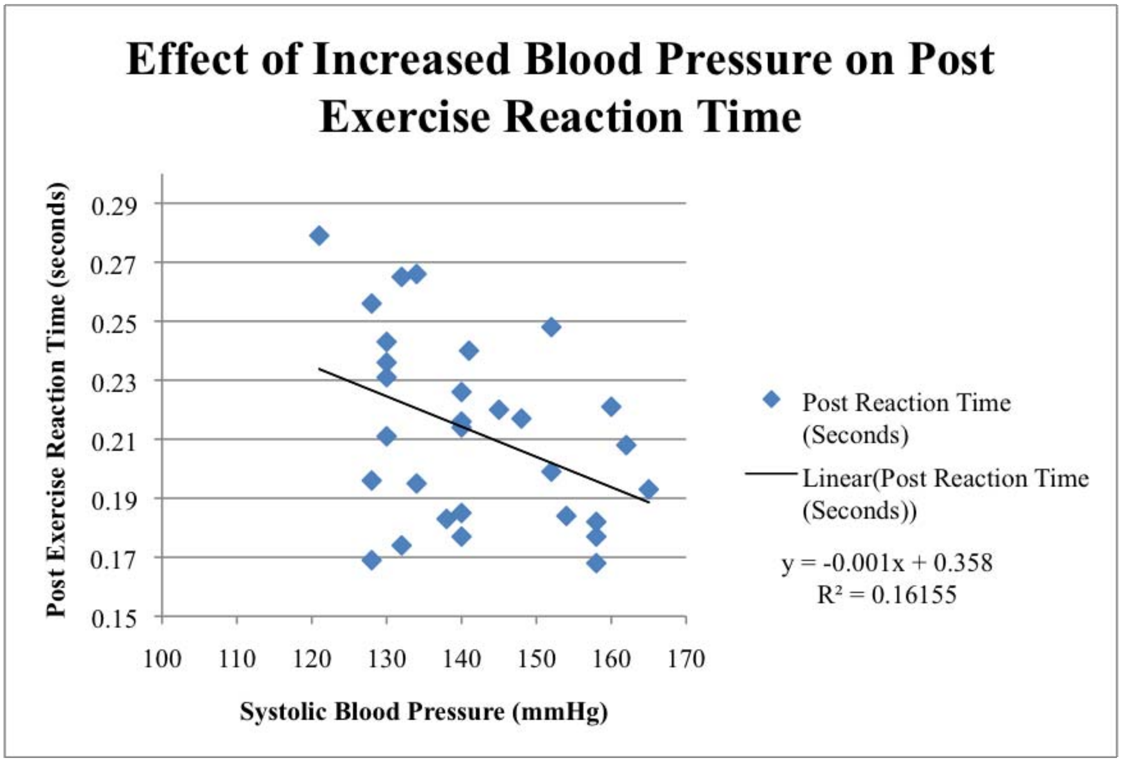

Figure 7: Post acute exercise auditory reaction time as a function of systolic blood pressure, N=30.

Figure 8

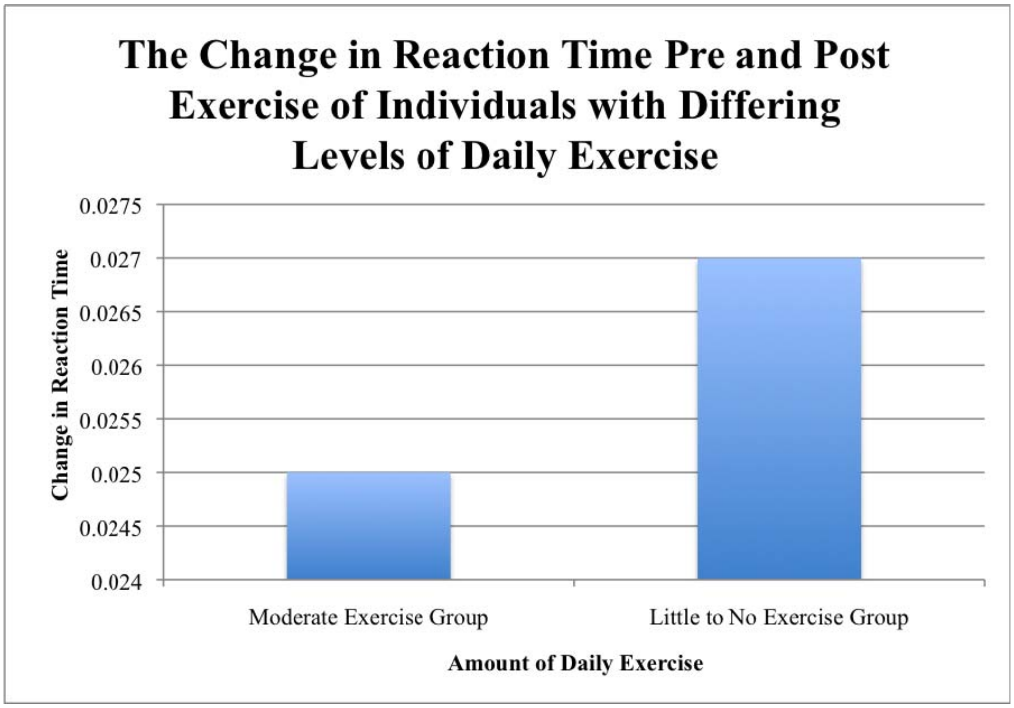

Figure 8: Average change in auditory reaction time between resting reaction time and post acute exercise. Subjects were grouped into moderate exercise group exercised three days or more per week for at least 30 minutes each session. Subjects within the little to no exercise group exercise 2 or fewer days per week for at least 30 minutes each session, N=30.

Figure 9

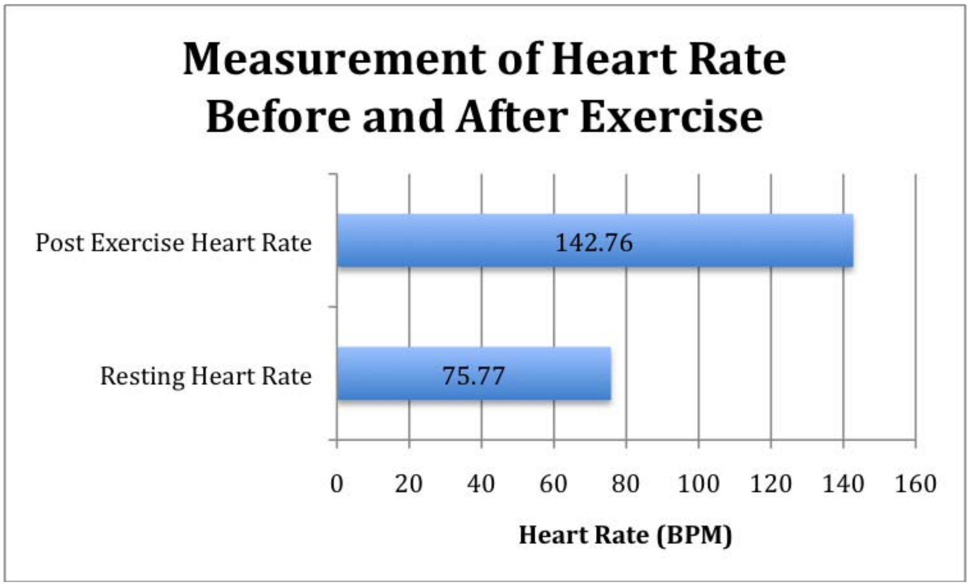

Figure 9. Immediate change in resting heart rate and post acute exercise heart rate for each individual subject. Post systolic blood pressure taken within one minute of completion of acute exercise, N=30.

Figure 10

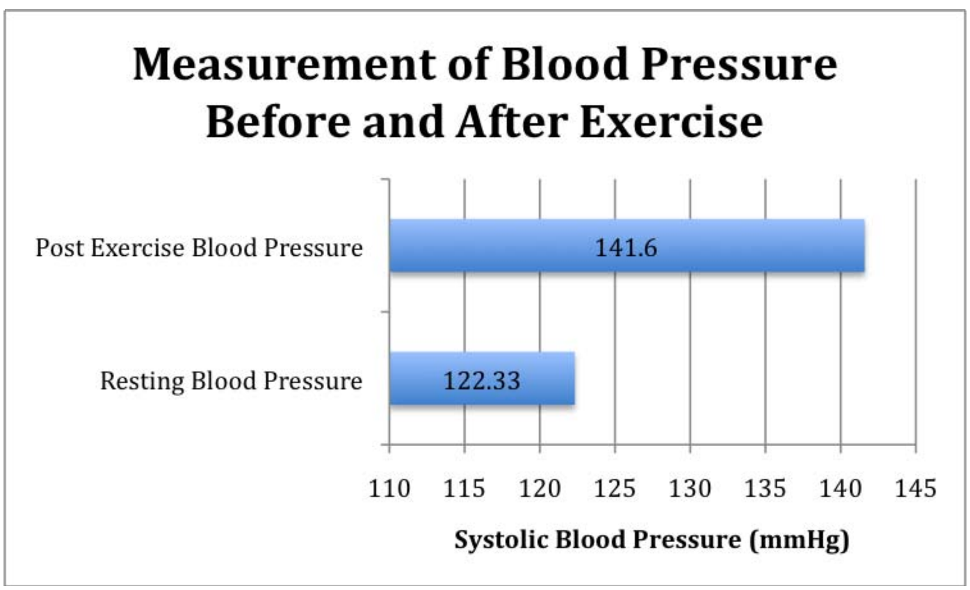

Figure 10. Immediate change in resting systolic blood pressure and post acute exercise systolic blood pressure for each individual subject. Post systolic blood pressure taken within one minute of completion of acute exercise, N=30.

Figure 11

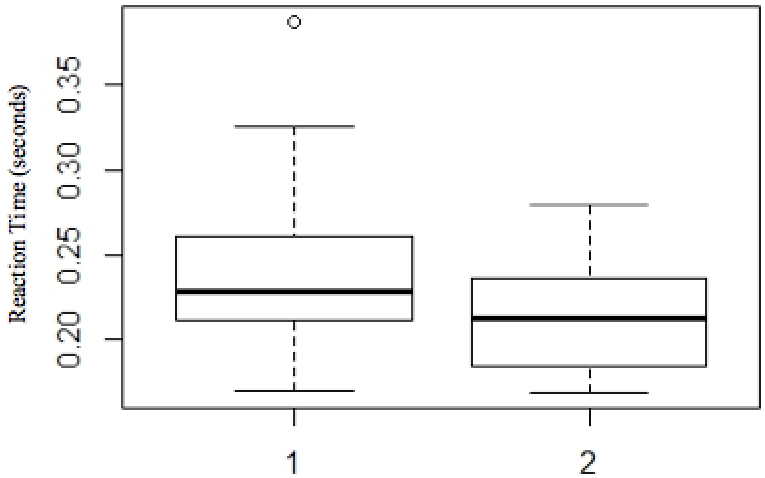

Figure 11. a) Quartile results for two groups, pre-exercise reaction times, 1, and post exercise reaction times, 2. N=30. b) One outlier present within pre-exercise reaction time group.

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