The effect of aerobic exercise on patellar reflex strength

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Abstract

To test the effect of exercise on reflex strength, 16 individuals were subjected to exercise on a stationary bike. Their patellar reflex, heart rate, and blood pressure were measured before exercise and at intervals of 0, 2.5 and 5 minutes after exercise. Using electromyography (EMG), the peak amplitude (mV), and area ($mV \cdot s^2$) of muscle contraction due to patellar reflex were measured. The measurements post-exercise were compared to those at rest to see if there were statistically significant differences. Results showed a significant increase in patellar reflex maximum amplitude at 2.5 minutes post-exercise compared to resting values (60% higher). Other time points, immediately after and 5 minutes after exercise, showed no significant difference related to resting values. Reflex strength as measured by area from the EMG readings also showed no significant difference compared to resting. There were no significant differences between males and females in terms of reflex amplitude, as well as no differences between groups with high weekly exercise relative to those with lower weekly exercise. This data supports the hypothesis that exercise increases patellar reflex strength. However, there appears to be a limitation on the time frame in which this increase is apparent.

Introduction

A reflex is a response elicited by a stimulation of the periphery, transmitted to the central nervous system, and back to the periphery. Many reflexes serve important roles in protecting the body from harm, such as the eye blink reflex. Other reflexes work to maintain homeostasis within the body (Mann, 1997). Reflexes in the periphery help regulate load compensation and muscle enhancement through simple feedback control (Hortobagyi, 1991). Thus, they play a crucial role in the survival of many organisms. Reflexes can be used as a clinical indicator of the condition of nerve circuits in the spinal cord or in the brain stem. The state of a reflex circuit can vary depending on the condition of the person (exercise, resting, sleeping, and thinking) (Mann, 2008). Factors such as temperature and blood flow of the surrounding tissue influence the speed of nerve impulse conduction (Abramson, 1966).

The patellar reflex is somatic because it is produced by a stimulus in a segmentally related somatic structure. After the patellar tendon is tapped, 1a afferent nerve fibers are stimulated in the muscle spindle of the quadriceps muscle. An action potential travels up a sensory neuron to the spinal cord. Glutamate release causes a motor neuron to signal quadriceps contraction. Interneurons simultaneously release inhibitory neurotransmitters, preventing contraction of antagonistic muscles (hamstrings). This coordinated event results in the extension of the knee joint post-stimulation. (Mann, 1997)

The performance of the patellar reflex may be subject to variation. Previous studies have presented a possible correlation between patellar reflex and exercise. General results have shown that reflex contraction strength increases with exercise. Using electromyography (EMG), one study found a 15% increase in contraction amplitude after eccentric exercise (Hortobagyi, 1998). Another found that subjects had shorter reflex times after vigorous exercise (Kamen et al., 1981). We are assuming that there is both a heart rate and blood pressure increase due to exercise.

Intense exercise temporarily elevates epinephrine, a catecholamine that interacts with BETA2-adrenergic receptors (BETA2-AR). The activation of the receptors causes a sympathetic response, that is a fight-or-flight response. This response includes increased heart rate, blood pressure and temperature, and stimulation of the sympathetic nervous system (Berne). In endurance training, BETA2-AR stimulation affects contractile activity, the activity of metabolic enzymes, insulin resistance, and promotes shifts in muscle fiber-type shift (Sato, et al. 2011). Enhancement of these functions may lead to increased adrenergic stimulation and increased reflex strength.

Heart rate is a unit of measurement for the number of heart beats per minute. A normal resting heart rate is measured in terms of beats per minute (BPM) when a subject is at complete rest. For a normal adult, the resting heart rate ranges from 60-100 BPM, while an experienced athlete has a resting heart rate close to 40 BPM (University of Florida, Recreational Sports, 2012). During exercise, the heart works harder by pumping more blood to deliver more oxygen to the rest of the body's muscles; this causes the heart's blood flow to increase four or five fold from the normal resting state with the heart increasing its BPM. Exercise-conditioned heart rates generally range from 60% to 85% of maximum. The sympathetic nervous system also plays a large role in exercise by mediating the constriction of the smooth muscle layer in the tunica media of the arterial wall, increasing the amount of blood returned to the heart, as well as increasing the blood pressure (Hedelin, 2001).

While at rest, a normal (non-hypertensive) individual's systolic blood pressure (SBP) typically falls between 120-129 mmHg, with diastolic blood pressure (DBP) ranging from 80-84 (Kravitz 2001). However, an individual's blood pressure increases during exercise, with SBP reaching over 200 mmHg. During exercise, cardiac output increases considerably in order to provide muscles with an adequate blood supply. This increase in output, combined with vasoconstriction in non-exercising vascular beds, causes an increase in SBP (MacDonald, 2002). At the same time, there is a decrease in total peripheral resistance as well as significant vasodilation in exercising muscles, both of which help buffer this increase and lead to a minimal rise in mean blood pressure. Still, this change in blood pressure often parallels the intensity of the exercise performed, with SBP showing a very close correlation (Koeppen and Stanton, 408; MacDonald 2002). In this study, we have measured subjects' blood pressure both before and after exercise in order to determine the relationship between blood pressure and patellar reflex response.

Materials and Methods

This study was designed to test the effect of exercise on reflex strength. A total of 16 subjects were tested of which 8 were male and 8 will be female. All subjects were between the ages of 20 and 25 and filled out an anonymous survey about age, gender, and exercise frequency, as well as a consent form, matched with the recorded data. The survey was used to further examine any possible correlations between reflex strength and these variables. Resting heart rate and blood pressure were taken before exercise. Reflex strength was also measured before exercise and the disconnected electromyography machine (EMG) electrodes remained on the subject's leg to ensure consistent placement. Subjects then exercised on a stationary bike until their heart rate reached 150 beats per minute. For the age group examined, this heart rate is considered a moderate exercise heart rate (CDC). When this heart rate was reached, the exercise was stopped and measurements of patellar reflex contraction strength via EMG immediately after exercise, 2.5 minute after exercise, and 5 minutes after exercise were made. Blood pressure and heart rate were both monitored at the same time intervals.

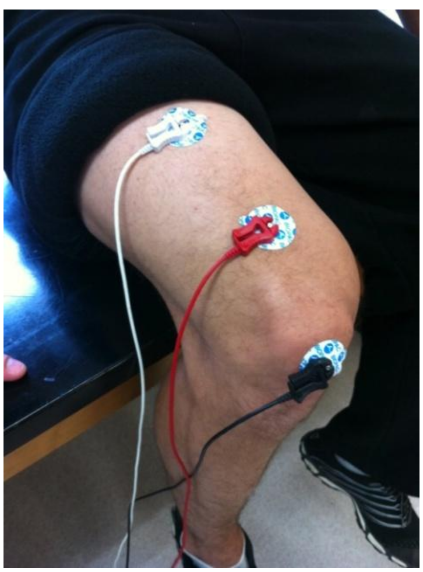

Figure 1. Electrode placement on the knee and thigh.

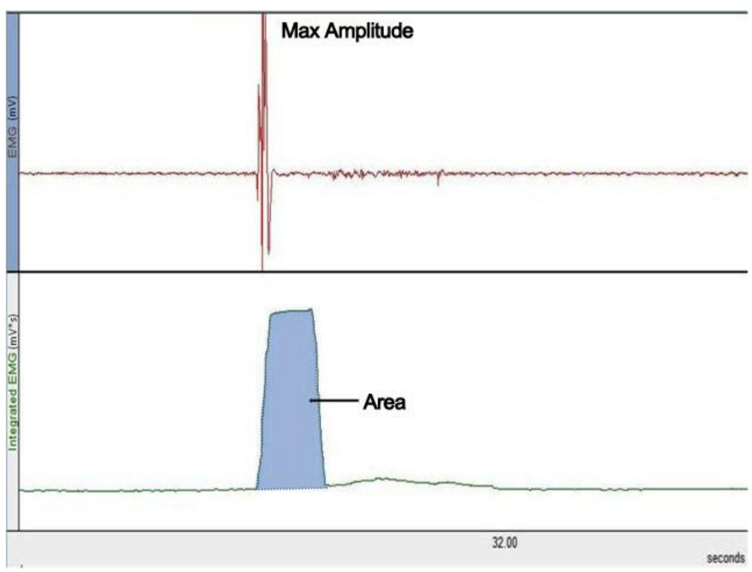

Figure 2. Example EMG Readings with maximum amplitude (top) and area (bottom).

Reflex Strength

An EMG was used to examine and quantify the strength of patellar reflexes in test subjects, (BIOPAC MP30B-CE). The machine works by calculating the electrical signals of muscles within its input plates. We used EMG electrode placement as specified by BIOPAC Systems Reflex Response Lesson: one on the subject's knee (ground electrode) and two on the thigh (recording electrodes), 10 centimeters apart (Figure 1). When the patellar reflex was triggered by a reflex hammer swinging from a horizontal angle, recorded maximum and total contraction area of the reflex. Five trials, 10 seconds apart, for each time period were taken and the 3 most consistent readings were averaged. Those readings that were especially low or high were considered outliers.

In order to account for the differences in individual reflex strengths among subjects, we calculated the ratio between the average maximum amplitude at each sample point and the average amplitude at rest. The same method was used for the average area as given by the EMG. Analysis of variance (ANOVA) and t-tests were used to determine statistical differences between groups with $P<0.05$ considered to be statistically significant.

Heart Rate

In relation to heart rate and autonomic reflexes, it is understood that heart rate is one of the many variables that increases due to exercise intensity (Savonen, 2006). However, to the best of our knowledge, heart rate is not known to directly influence the autonomic responses similar to how an increase in exercise intensity may or may not have a more direct effect in faster autonomic reflexes. Heart rate increase is identified to be a positive control after exercise intensity. Manual readings of heart rate were taken at the wrist of each subject.

All individuals had different levels of endurance which affected how long it took each to reach a certain level of exercise intensity. In order to observe the reflex we needed to control the level of intensity that the individuals reached. The subjects needed to reach their target heart rate before we measured the patellar reflex. This accounted for the differences in time that it took individuals to reach the set intensity level.

Heart rates were averaged and statistically compared among individuals using standard deviation.

Blood Pressure

Due to the correlation between increased exercise and blood pressure, we used a blood pressure cuff to measure the relationship between exercise and increased blood pressure. An electronic Omron HEM-712C monitor was used to measure blood pressure in all subjects. This measurement was used to support the analysis of intensity observed by the heart rate measurements. Standard deviations and averages were calculated from the data collected.

Results

Following exercise, the patellar reflex showed an increase in contractile strength. Significant increases were seen at 2.5 minutes following exercise while no significant changes in reflex strength were observed at 0 minutes and 5 minutes following exercise compared to resting values (Table 1).

Table 1: Summary of data highlighting statistically significant P-values in red.

	Max. Amplitude			Area		
	Relative Average	**St. Dev.**	**P-value**	**Relative Average**	**St. Dev.**	**P-value**
Rest	1	-	-	1	-	-
0 min.	0.97	0.27	0.90	0.92	0.92	0.49
2.5 min.	1.60	0.41	0.02	1.38	0.87	0.09
5 min.	1.34	0.36	0.15	1.19	0.85	0.37
ANOVA	-	-	0.02	-	-	0.09

ANOVA of the data for the relative maximum amplitude of contraction indicated that significant statistical differences exist between the groups examined (P=0.02). Pair wise comparisons between groups showed that significant differences in amplitude between resting and 2.5 minutes post-exercise (P-0.02, t-test), but not between resting and amplitude recorded at 0 or 5 minutes post-exercise (Table 1).

Figure 3 shows the peak in relative maximum amplitude at 2.5 minutes compared to resting. Reflex amplitude at this time was 60.2% higher than at rest. At 5 minutes, the average amplitude of maximum contraction was still approximately 35% higher than at rest, but this difference was not statistically significant (p-value=0.15). Immediately after exercise, there was little change in average relative amplitude compared to rest and no significant difference between the two. Standard deviations are shown with the corresponding averages at each time point.

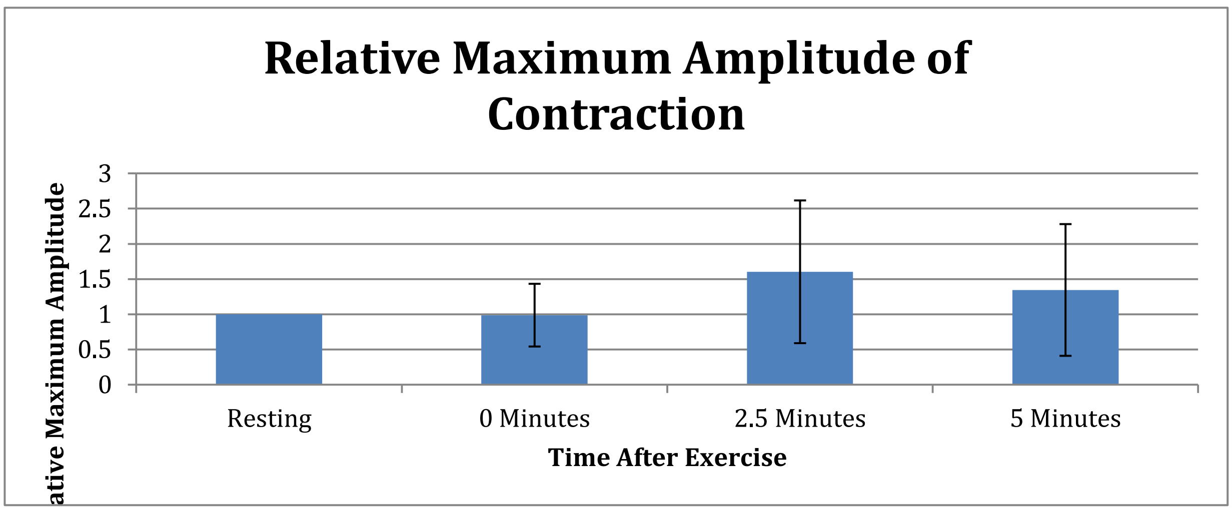

Figure 3. Relative Maximum Amplitude of Contraction. Average maximum contraction amplitude, as measured by EMG, at each time point relative to the resting maximum contraction values.

When we ran this data through an ANOVA test, we found no significant statistical difference between the groups examined (P-value=0.09). After further analyzing the data sets, we found t-test values of 0.49 for the difference between resting and immediately after exercise, 0.09 between 2.5 minutes post-exercise and resting, and 0.37 between 5 minutes post-exercise and resting. All t-test pair wise comparisons therefore showed not statistical differences.

Figure 4 shows relative contraction area compared to resting reflex contraction area. Immediately after exercise, there was approximately a 10% drop in average contraction area compared to rest and no significant difference between the two. Contraction area at 2.5 minutes was 38.2% higher than at rest. At 5 minutes, the average area of contraction was still approximately 20% higher than at rest, but this difference was not statistically significant. Standard deviations are shown with the corresponding averages at each time point.

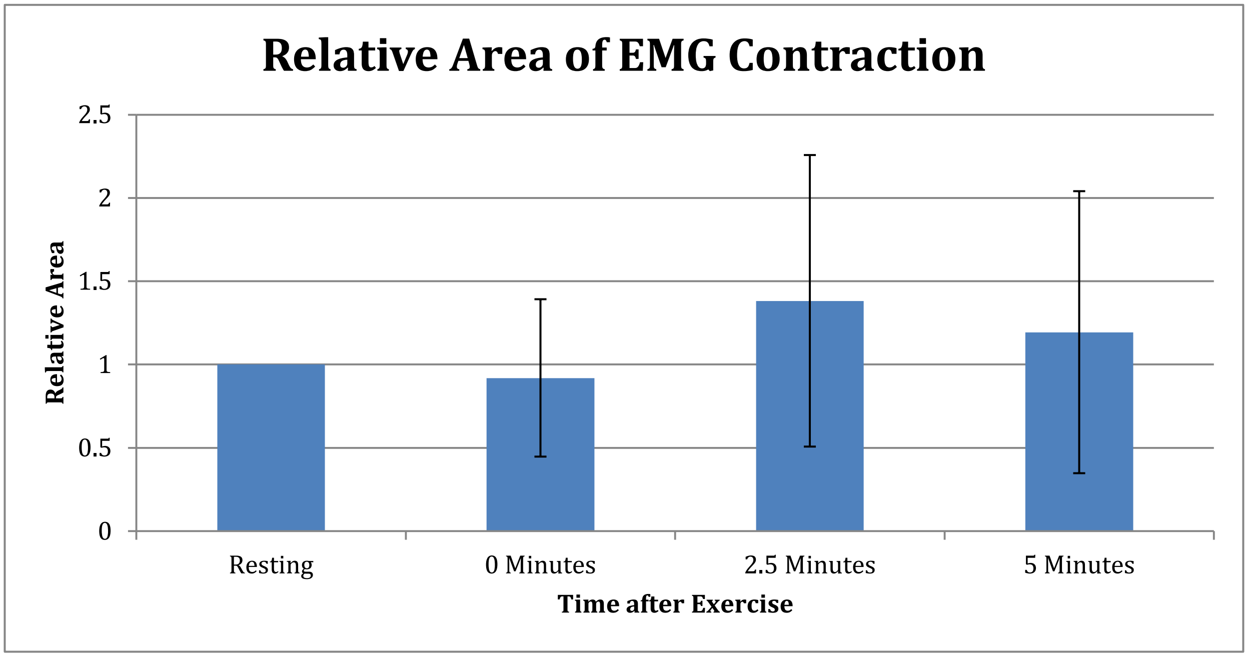

Figure 4. Relative Area of EMG Contraction. Average contraction area values, as measured by EMG, at each time point relative to the resting contraction area values.

There were no statistical differences between relative maximum amplitude among male and female subjects at any of the time points examined. Both groups showed a similar trend with a spike in relatively maximum amplitude at 2.5 minutes compared to resting values; 57% higher for females and 63% higher for males(P=0.98, t-test). Time points immediately after exercise were not statistically different between males and females (P=0.89) and remained only minimally changed from resting values; 1% lower for males and 2% lower for females. The data 5 minutes after exercise also indicated no statistical differences (P=0.70, t-test) although it remained somewhat elevated when compared to resting; 7% for females and 59% for males. Standard deviations are shown with the corresponding averages at each time point.

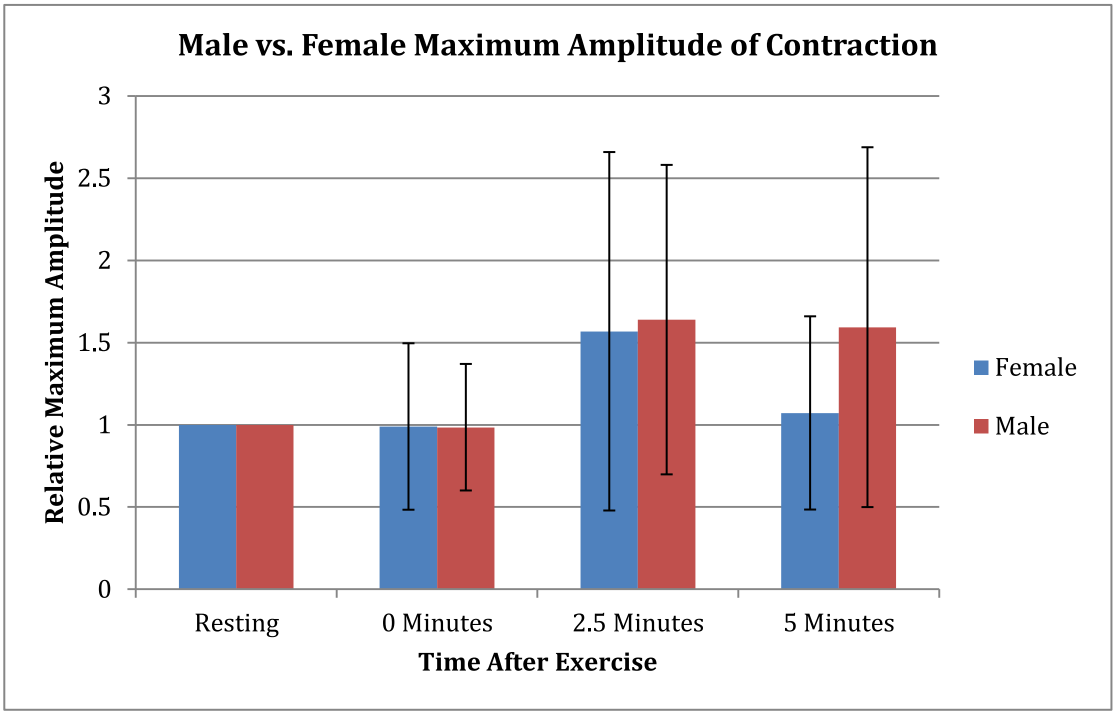

Figure 5. Male and Female Subject Maximum Amplitude of Contraction. Average maximum contraction amplitude, as measured by EMG, at each time point relative to the resting maximum contraction values. Data sets were divided by gender.

There was no statistical difference comparing relative maximum amplitude among groups with high and low levels of exercise at any time point. Three hours was chosen as the dividing point between the two groups because it was the median data point for weekly exercise of the subjects examined (Figure 6). Both groups showed a similar trend with a spike in relative maximum amplitude at 2.5 minutes compared to resting values; 63% higher for less than 3 hours and 58% higher for greater than 3 hours. However, there was no statistical difference between the groups (P=0.55, t-test). Time points immediately after exercise were not statistically different between males and females (P=0.92, t-test) and remained only minimally changed from resting values; 6% higher for less than 3 hours and 8% lower for greater than 3 hours. The data 5 minutes after exercise also portrayed no statistical difference (P=0.66, t-test) and remained somewhat elevated when compared to resting; 24% higher for less than 3 hours and 45% higher for greater than 3 hours. Standard deviations are shown with the corresponding averages at each time point.

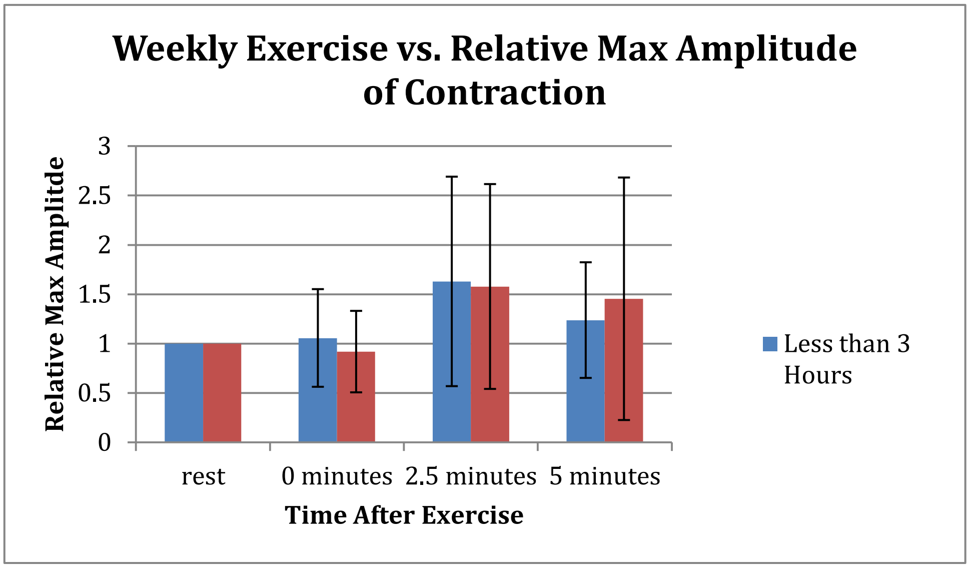

Figure 6. Weekly Exercise vs. Relative Max Amplitude of Contraction. Average maximum contraction amplitude, as measured by EMG, at each time point relative to the resting maximum contraction values. Data sets are split by weekly exercise duration (3 or more hours and less than 3 hours).

The average heart rate and systolic blood pressure were plotted together, with the relative maximum amplitude of contraction on a secondary axis, in order to examine the trends in the variables in relation to one another (Figure 7). As expected, heart rate and systolic blood pressure seemed to be related as changes corresponded at rest and between each of the time points examined following exercise. Changes in reflex strength did not show as clear a correlation, however, it is possible that there is still a relationship, albeit delayed.

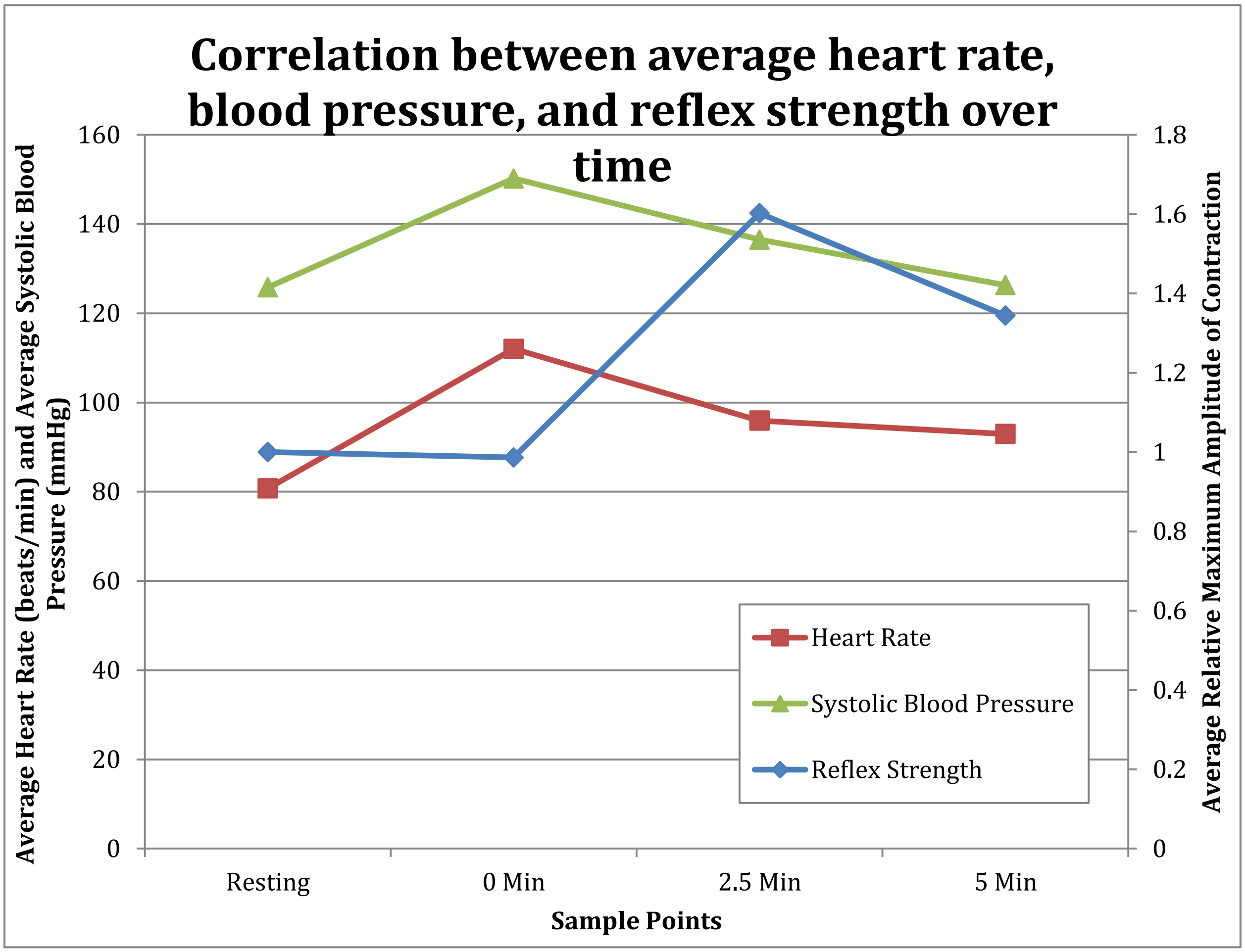

Figure 7. Correlation between average heart rate, blood pressure, and reflex strength over time.

Discussion

After analyzing the data across all available variables, we concluded that patellar reflex strength did increase post-exercise, thus supporting our hypothesis. This conclusion was based on the statistically significant increase in patellar reflex strength (60.2%) as shown by the relative maximum amplitude data at 2.5 minutes post-exercise.

The most likely explanation for this observed increase in reflex amplitude is the heightened sympathetic nervous stimulation during exercise. The sympathetic pathway controls the fight-or-flight response and elevated sympathetic input to muscles may cause reflexes to be over-active compared to resting levels, which would be dominated by the parasympathetic pathway.

We observed a consistent trend that patellar reflex strength did not increase immediately after exercise. This was most likely due to muscle fatigue experienced by the subjects. During our tests, the subjects specifically mentioned that their legs felt tired immediately after exercise and thus their reflexes felt subjectively weak. The fatigue was reflected the lack of statistical difference between resting reflex amplitude and immediately post-exercise reflex amplitude (-1.4%).

We can also account for the lack of statistical difference between resting reflex amplitude and 5 minutes post exercise reflex amplitude (34.4%). The effects of exercise, namely heart rate and blood pressure, are known to return to baseline levels once exercise is completed. How quickly this occurs depends on the fitness of the individual and intensity of exercise, but in our case, it seems that 5 minutes was enough for most subjects to return to near resting levels of heart rate and blood pressure.

While we did find reflex amplitude to go up after exercise, there were a number of error sources that we came across. One that came up multiple times was an apparent muscle fatigue for the subjects influencing their reflex strength. A few subjects mentioned specifically that they felt their muscles being tense immediately after exercise and that this may have lowered the value of the relative maximum amplitude of contraction. This may explain the lack of change between resting reflex values and those immediately after exercise. This fatigue may act to reduce contraction strength as seen by EMG recordings even if a higher reflex signal is sent to the muscles.

In some cases, difficulties with the equipment were also encountered. First, the pulse oximeter that was tested did not show consistent heart rate data when subjects were exercising. This forced us to use manual readings of the wrist in order to achieve consistent real time data. Human error was limited in this case by having the same experimenter test heart rate in all cases. The method used to apply the reflex hammer may also have increased error in these experiments. In future, it might be useful to have an apparatus to consistently swing the hammer. Each subject had a different position on their knee which responded best to a hammer strike and adjusting to this took a few test strikes in order to find the correct placement. These sources of error may have created a higher than expected level of variability in the subjects' reflex strength. Lastly, it is impossible for us to know if our subjects were fully compliant with our instructions when performing the reflex test itself. In order for the reflex to be measured accurately, a subject's leg must be completely relaxed. Tensed muscles will result in lower values of contraction strength. There was a wide variation in visible reflex response seen throughout these experiments and part of this may have related to variable tension in the test subjects.

In order to further the results of these experiments in the future, it would be advantageous to include more subjects, as well as additional time points. Unfortunately, it was impossible for us to measure true real-time data and instead we were limited to 2.5 minute intervals. A constant stream of data may have permitted more trends to emerge and a reduction in overall variability.

There was a very high amount of variation between subjects, and thus, underlying inconsistencies may be present in the data. More test subjects would help minimize some of these differences, as well as help in the identification of outliers. It would also be useful to use a more consistent mechanism for swinging our reflex hammer. This could potentially help lower the variability within each subject's readings because the force of the blow from the hammer directly affects the reflex response. In addition, it would also be appropriate to stabilize and standardize the position of the subject's thigh during the tendon tap. Another variable that could be added to the experiment would be reflex timing. While we did find that at certain time points, reflex strength increased, we did not record reflex time in our test. A lowering of reflex time with exercise would also serve to verify the results obtained. If exercise does "increase" reflexes, it may do so in more than one way and may not be limited to contraction strength, but may include reaction time.

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