The Effect of Exercise Intensity Level on Auditory Response Time

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Key Words:

Auditory, Blood Pressure, Exercise, Response Time, Sympathetic Nervous System, Conduction Velocity, Intensity Level, Heart Rate, Epinephrine, Signal Transduction

Abstract

This study investigated the effects of different exercise intensity levels on participants' auditory reaction times. 24 undergraduate students (mean age = 21.6 years; 58% male, 42% female) at the University of Wisconsin-Madison were randomly assigned to 1 of 3 groups in order to test the effects of exercise intensity on auditory reaction time. The first group served as a control and remained sedentary for 15 minutes, while the other 2 groups exercised on a stationary exercise bike for 15 minutes within target heart rate ranges for moderate intensity (100-140 bpm) or high intensity (140-170 bpm). Heart rate, blood pressure, and auditory reaction time was measured pre- and post-exercise for each participant. Auditory response time decreased significantly for individuals in the high intensity exercise group and approached levels of significance for individuals in the moderate intensity exercise group.

Introduction

Reaction time is the interval between the onset of a stimulus and the appearance of an appropriate voluntary response by the subject (Pritesh, 2013). Reaction time can be divided into three distinct intervals: the time necessary for perception of the stimulus, the time needed to select a response to the stimulus, and the time required to carry out the response. The mechanism of the auditory response to stimuli involves a complex conversion of sound waves from the environment into action potentials in the auditory nerve. These signals are carried through the central auditory pathway to the primary auditory cortex, or Brodmann's area 41 (Raff, 2011). The brain, acting as the body's integrating center, then sends a signal to the appropriate effectors in order to generate a motor response to the initial stimulus (Pritesh, 2013). On average, the time necessary to react to an auditory stimulus is approximately 170 ms (Senel, 2006). Understanding the physiological factors affecting auditory response time is important because it may offer possibilities for improving safety measures in society. For example, the ability to operate a motor vehicle or react to a stimulus during a stressful situation relies on responses mediated by the auditory pathway. Thus, determining how responses to auditory stimuli can be improved may decrease the number of incidents with hearing-related causes.

Exercise or physical activity carried out with the intention to sustain improvements in health, causes a number of physiological changes in the body including increases in blood pressure, heart rate, and body temperature. These responses occur because physically strenuous activity stimulates the release of epinephrine and norepinephrine from the adrenal medulla into the bloodstream, which activates the sympathetic nervous system and triggers the body's "fight or flight" response (Raff, 2011). Another important consequence of epinephrine and norepinephrine release is that it heightens the speed of impulse conduction throughout the central and peripheral nervous systems (Abramson, 1966). The “fight-or-flight” response also involves the release of cortisol from the adrenal cortex. Cortisol increases plasma blood glucose levels and heightens alertness by supplying the brain with a fuel source. Therefore, the overall effect of autonomic arousal is to enhance the rate of impulse conduction throughout the CNS and PNS, respectively. This increased nerve conduction velocity has been shown to enhance the strength of the body’s somatic reflexes (Paulsen, 2012).

Since the auditory response pathway is dependent upon signal transduction throughout the CNS and PNS, it is hypothesized that the heightened conduction velocity due to exercising should facilitate a faster response to auditory stimuli. Furthermore, it is predicted that the improvement in auditory reaction time will be proportional to the intensity level of the exercise. That is, no effect will be observed for a no exercise control group while moderate levels of exercise intensity will elicit moderate decreases in response times to auditory stimuli, and high levels of exercise intensity will elicit greater decreases in response times.

To test the effects of exercise intensity level on auditory reaction time, subjects will engage in 15 minutes of continuous exercise at a target heart rate (HR). One group will perform moderate intensity exercise, which is defined as a HR of 50-70% of the maximum HR. For this study, the maximum HR was designated as 200 bpm based upon participant demographics (CDC Website, 2011). A second group will perform high intensity exercise, which is defined as a HR of 70-85% of the designated maximum HR. A third group will serve as a control and perform no exercise. Pre- and post-exercise systolic blood pressure will be measured and utilized to ensure that the desired level of exercise intensity was achieved. Pre-exercise auditory response times will be compared to the subject’s response time after exercise to determine the effect of exercise intensity level of auditory response times.

Methods

Participants

Participants were students (mean age = 21.6 years; 58% male, 42% female) at the University of Wisconsin-Madison enrolled in Physiology 435 that were recruited during the weekly laboratory period. On average, participants engaged in approximately 5.1 hours of exercise per week and slept approximately 6.9 hours per night. None reported a physical condition that could prevent them from engaging in exercise.

Materials

Participants signed consent forms (Appendix A) and completed a short questionnaire (Appendix B) about demographic and exercise- and sleep-related habits. Pre- and post-exercise HR was measured using a Nonin Model 9843 fingertip monitor. Pre- and post-exercise blood pressure was measured using a digital wrist blood pressure monitor. Pre- and post-exercise auditory response times were measured on a Dell Inspiron 530 computer using a Biopac Systems SS10L Push Button Hand Switch, Behringer HPM1000 headphones, and BIOPAC Student Lab 4.0 software. Lastly, participants exercised on Schwinn BioDyne exercise bikes, and an iPhone 5S stopwatch application was used to monitor the amount of time spent exercising.

Procedure

Participants were recruited during Physiology 435 laboratory periods, asked to read and sign consent forms, and randomly assigned to experimental groups. Pre-exercise HR, blood pressures, and auditory response times were measured using the equipment described above. The procedure for measuring auditory response times is described in the BIOPAC Laboratory Manual (2010). Measurements of HR and blood pressure were taken to ensure that subjects had resting rates within the normal range. Based upon their randomly assigned experimental group, participants either engaged in 15 minutes of sedentary activity (i.e. sitting), moderate levels of exercise intensity, or high levels of exercise intensity. Schwinn BioDyne exercise bikes were used for the exercise. Moderate and high exercise intensity levels groups were defined as maintaining a HR within the range of 50-70% and 70%-85% of the maximum HR for 15 minutes, respectively. Afterwards, post-exercise HRs, BPs, and auditory response times were measured to determine the effects of moderate and high levels of exercise intensity on these three measures. Participants then completed a short survey (Appendix B) collecting demographics and information about exercise- and sleep-related habits. The experimental timeline is depicted in Figure 1.

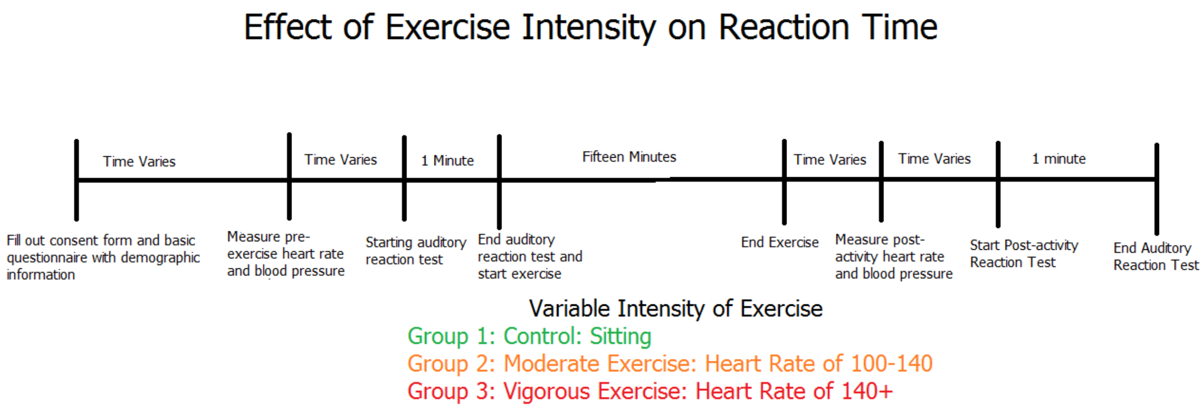

Figure 1: Timeline of Experiment

For a positive control, we intentionally raised the heart rate and blood pressure of participants by having them perform exercise for 70 seconds. We measured heart rate and blood pressure before, during, and after exercise. Tables 1 and 2 show that we were successful in manipulating participants' heart rate and blood pressure via exercise.

Time	Heart Rate
0	73
10	75
20	78
30	77
40	95
50	113
60	118
70	117
80	123
90	137
100	137
110	135
120	117
130	121
140	104
150	96
160	91
170	84
180	78
190	77
200	79
210	75
220	76
230	77

Table 1: Participants heart rate before, during, and after a 70 second exercise period (time = 40 to 110) of exercise.

Time	Systolic BP	Diastolic BP
0	128	81
60	139	89
120	147	109
180	139	110
240	132	81
300	129	79

Table 2: Participants systolic and diastolic blood pressures before, during, and after a 70 second exercise period (time = 40 to 110) of exercise.

Statistical Analysis

In order to quantify the effects of exercise intensity on auditory response times, an ANOVA test will be conducted. This will simultaneously test the means of multiple groups to see if they are equal. The null hypothesis is that the groups will not have equal means. By using an ANOVA test rather than a two-sample T-test, the chance of encountering a Type 1 statistical error will be greatly lessened. If there is a significant difference between groups, the data can further be evaluated to determine where the differences lie between groups. The Tukey-Kramer is an unplanned, post-hoc analysis that will compare the means of each group in pairs, divided by the standard error across groups. It is similar to two-sample t-tests, but has a larger critical value in order to lessen the risk of Type I errors. The ANOVA test establishes whether there are differences between the groups, while the Tukey-Kramer is able to establish more specifically which groups are different from each other.

Results

Heart Rate

All participants were able to achieve their target heart rate within 1 to 2 minutes of beginning exercise. As illustrated in Figure 2, both the moderate and high intensity experimental groups significantly increased their HR relative to the control group. The average change in HR for the control, moderate and high intensity level exercise groups were -5.25, 61.875 and 77.375 bpm, respectively. Importantly, the data also suggests a negative correlation between HR and ART for both the moderate and high intensity level exercise groups.

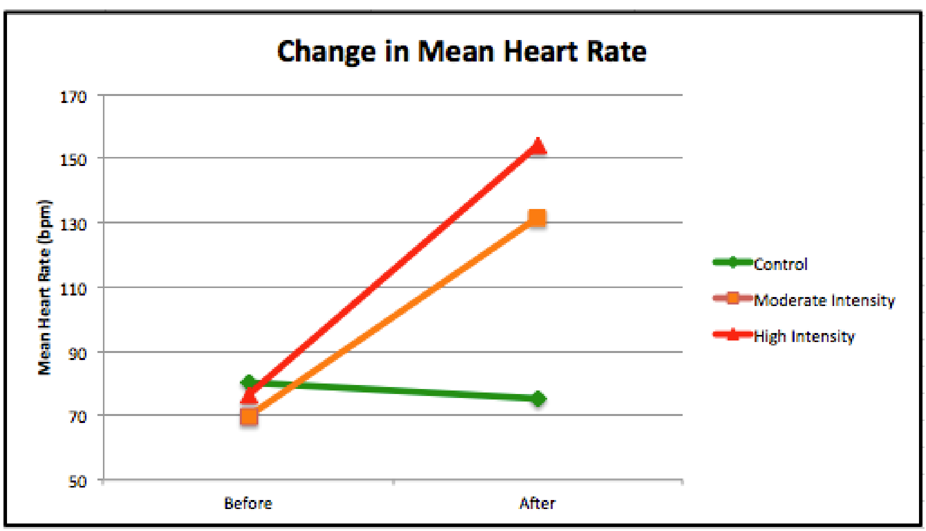

Figure 2: Average heart rate obtained before and after experiment in beats per minute.

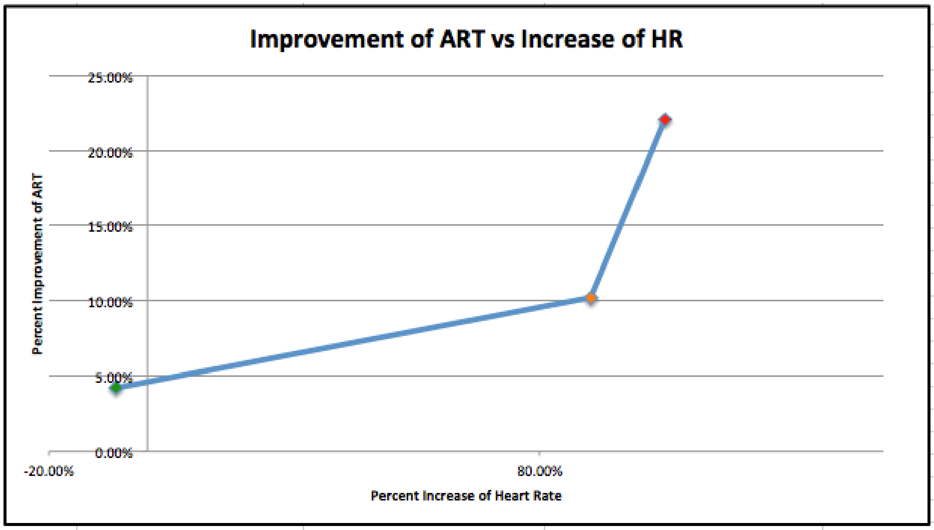

Figure 3: Auditory response time improvement vs. an increase in heart rate in terms of percentages of the max.

Blood Pressure

Upon comparing the baseline blood pressure measurements to the blood pressure measurements taken after being subjected to exercise, a significant difference is observed in systolic blood pressures. The data demonstrates no significant trend of changes in diastolic blood pressure. The average changes in systolic BP for the control group, moderate intensity group, and high intensity group were -4.00 mmHg, 9.75 mmHg and 12.50 mmHg, respectively. These values translate to a 3.039% decrease for the control group, a 7.702% increase for the moderate intensity group, and a 10.445% increase for the high intensity group. As depicted in Figure 4, this data suggests that systolic BP increases proportionally with exercise intensity. The changes

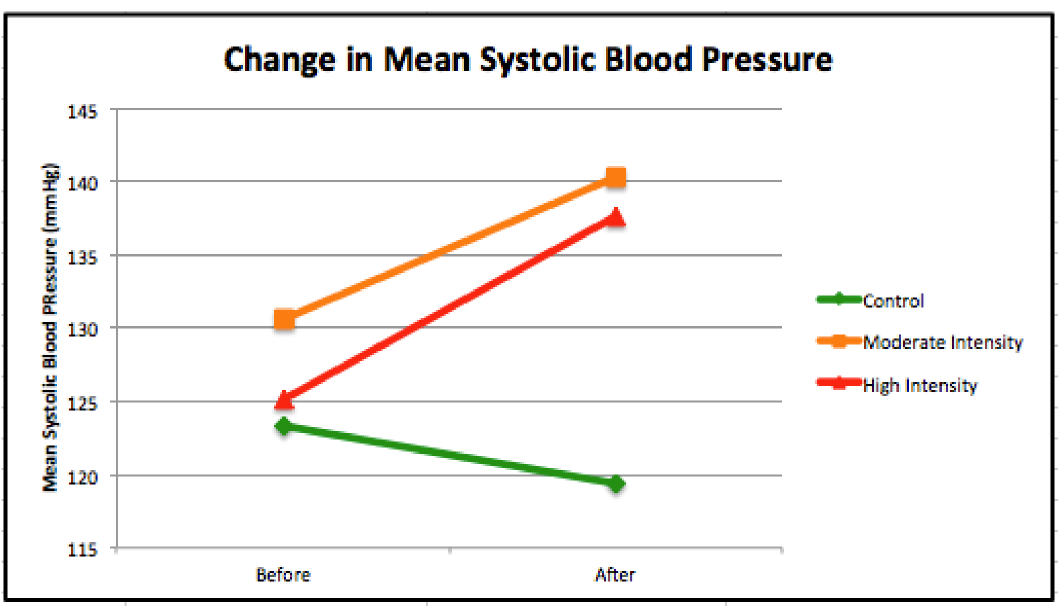

Figure 4: Average systolic blood pressure in mmHg before and after the experiment.

of diastolic BP of -2.50 mmHg, 6.75 mmHg, and 3.00 mmHg for the control, moderate intensity, and high intensity groups respectively, demonstrate no correlation with exercise intensity level.

Auditory Response Time

As illustrated in Figure 5, the high intensity group experienced the largest decrease in mean auditory response time of -0.0546 ms, an improvement of 22.031% compared to baseline measurements. The mean auditory response times of the control and moderate intensity groups also exhibited decreases of -0.0134 ms and -0.0258 ms, or 4.231% and 10.191% from their respective baseline measurements. To determine whether the intensity level of exercise affected auditory response time, an analysis of variance (ANOVA) test was conducted. The results of the test showed that the null hypothesis had been rejected, and there were significant differences between the means of the three groups, with a p-value of 0.00879. Therefore, a Tukey-Kramer test was administered to determine which groups had significant differences between them. After calculating the q values of the different pairs, and comparing it to the critical q-value with the appropriate degrees of freedom, it was concluded that there was a significant difference between the groups of control and high intensity.

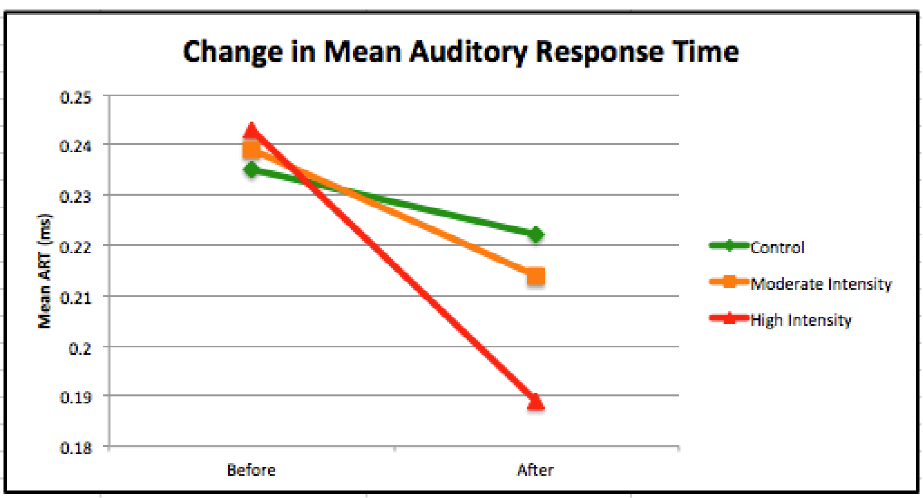

Figure 5: Average auditory response times measured in milliseconds before and after the experiment.

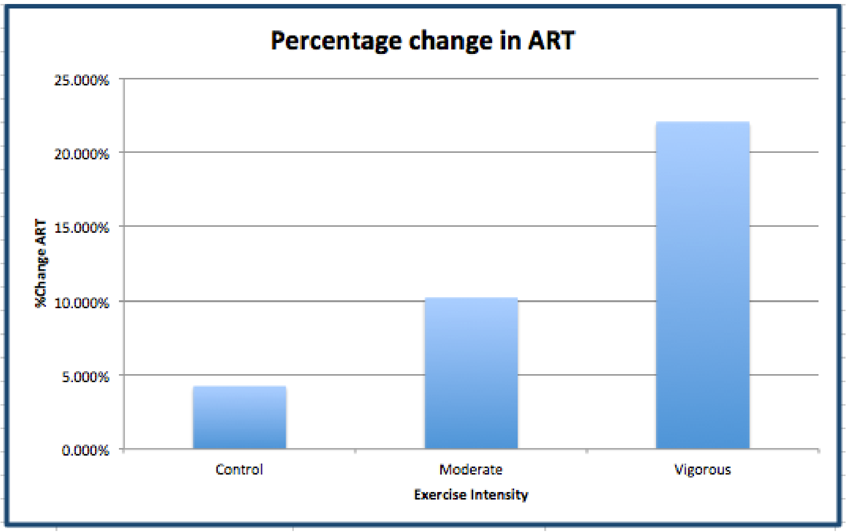

Figure 6: The improvement of the auditory response time in terms of percentage for the three experimental groups.

Evaluating Participant Survey

Upon evaluation of the data from the participant survey, there was no remarkable correlation between age, hours of sleep per week, hours of exercise per week and sex. These attributes showed no association with the measured BP, HR, or auditory response time.

Discussion

The purpose of the present study was to determine the effects of exercise intensity level on HR, BP, and auditory response time. Results suggest that exercising did improve the response time to auditory stimuli, but different intensity levels of exercise did not elicit differential effects, and the only statistically significant difference in means was between the control group and the high-intensity group. However, the q-value for moderate and high intensity was very close to the critical threshold, and therefore it would be conducive to examine the data and run this experiment again, with more participants. A sample size of 30 participants would likely be sufficient to reach this threshold.

The effect of exercise that facilitated a decrease in auditory response time is likely mediated through mechanisms related to sympathetic nervous system arousal. In particular, exercising likely promoted an increase in nerve conduction velocity (Erken *et al*., 2013), which would have led to an increase in mental alertness and reaction time (Huertas *et al.*, 2011).

A testing bias was observed for the control group when measuring HR and BP. For both HR and BP, the control participants, on average, had a decrease in HR and BP. The decrease can be attributed to an initial nervous state and general unfamiliarity when meeting strangers (those conducting the experiment) and participating a new study. This initially high HR and BP could also be attributed to a feed-forward mechanism. Participants were informed of the possibility of exercise and the purpose of the experiment before they were sorted into groups. Therefore, their HR and BP may have increased in anticipation of exercise, and after the fifteen minutes of not exercising, their heart rates had lowered. Lastly, the mean ART of all three groups decreased from the baseline measurements. The fact that even the control group exhibited an improvement in auditory response time suggests that test procedure bias may have played a role. Test procedure bias refers to improved participant performance due to familiarity with the procedure from a previous trial (Fuchs, 1986).

While the moderate and high intensity exercise participants showed increases in heart rate, there was an overall decrease in heart rate for the control group. This is somewhat out of line with expectations, which would dictate that there would be no change in heart rate while the participants were sedentary for the 15 minutes. However, a possible explanation for their originally higher HR and BP is the feed-forward mechanism. Participants were informed of the possibility of exercise and the purpose of the experiment before they were sorted into groups. Therefore, their heart rates may have increased in anticipation of exercise, and after the fifteen minutes of not exercising, their heart rates had lowered.

A possible future direction of this research may involve determining the duration of the beneficial effect exercise has on auditory response time. The test necessary would consist of a high intensity, long duration, workout. Based on the results of this paper, these conditions would ensure an improvement in ART. Following exercise an ART test will be administered every three minutes to observe the progressive expected return to baseline reaction time. This trend may be attributed to decreasing levels of epinephrine in the blood plasma post exercise. This study would also provide insight into the timeline of epinephrine degradation in the blood plasma.

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Appendix A

University of Wisconsin-Madison
Research Participant Information and Consent Form
Title of the Study: Exercise Intensity Level and Auditory Response Time

Principle Investigators: Sam Bauer, Angie Greenman, Luke Addesso,

Scott Fiedler, Kate Schneider

<u>Description of the Research</u>

You are invited to participate in a research study about the effect of exercise intensity on auditory response time. You have been asked to participate because you are currently enrolled in Physiology 435. The purpose of this research is to determine the effects of moderate and high levels of exercise intensity on one's ability to respond to auditory stimuli. This research will invite the participation of all students enrolled in Physiology 435 and will take place within Physiology 435 laboratory sections.

<u>What Will Participation Involve?</u>

If you decide to participate in this research you will be asked to engage in no, a moderate level, or high level of exercise for 15 minutes. Before and after the exercise, several physiological measurements will be taken including auditory response time. You will also be asked to fill out a short questionnaire. In sum, your participation will take approximately 25 minutes. After the semester is completed, you will be notified of any significant finding if you prefer. No credit will be assigned for your complete and voluntary participation. If you do not wish to participate, simply return blank this consent form.

<u>Are There Any Risks Involved?</u>

You should not participate in this research study if you have a history of heart problems or stroke.

Are There Any Benefits to Me?

Participating in this study offers you an opportunity to be involved in the scientific process and gain a better understanding of how physiology research is conducted.

How Will My Confidentiality Be Protected?

While there may be printed reports as a result of this study, your name will not be used. Only group characteristics will be reported – that is results with no identifying information about individuals will be used in any reported or publicly presented work.

Whom Should I Contact If I Have Questions?

If you are not satisfied with response of the research team, have more questions about the study, or want to talk with someone about your rights as a research participant, you should contact Dr. Andrew Lokuta at (608) 263-7488 or ajlokuta@wisc.edu.

Your participation is completely voluntary. If you decide not to participate or to withdraw from the study it will have no effect on your grade in this class.

You signature indicates that you have read this consent form, had an opportunity to ask any questions about your participation in this research and voluntarily consent to participate.

Name of Participant (please print):____

______________________________ ________________

Signature Date

Appendix B

<u>Participant Questionnaire</u>

Name:

Gender:

Age:

How many hours of exercise do you average per week? ________

How many hours of sleep do you average each night? ________

Do you have a heart condition or any other condition that prevents you from exercising?

____