Physiological Stress Response to Anticipation of Physical Exertion

Kelly Junk, Laura Peller, Holly Brandenburg, Ben Lehrmann, Evan Henke

University of Wisconsin-Madison, Department of Physiology

Physiology 435

Lab 603, Group 14

Word Count: 4285

Key Words:

Anticipation, Autonomic Nervous System, Blood Pressure, ElectroDermal Activity (EDA), Exercise, Feedforward Regulation, Heart Rate

Abstract

The physiological feedforward response is an unconscious phenomenon by which the body attempts to prepare itself prior to the onset of a stressor. In humans, this feedforward mechanism has been implicated in thermoregulation, digestion, and anticipation of physical activity. To test this feed forward response, we designed an experiment to measure physiological responses in human participants in anticipation to exercise to analyze how the body copes with the expected deviations from homeostatic conditions. Thirty participants completed an exercise-related survey designed to prime their bodies in anticipation of future exercise while heart rate, blood pressure, and EDA/skin conductance were measured. Following this anticipatory period, participants performed basic exercises while the same physiological measurements were collected. It was hypothesized that the physiological measurements taken during anticipation would be similar to those collected during exercise, with physically fit participants displaying a greater anticipatory response than the sedentary participants. Our results indicated that there were no significant differences in heart rate, blood pressure, or EDA between genders or varying fitness level groups. Because of the lack of significance in the three physiological tests, the null hypothesis cannot be rejected. Additional studies will need to be conducted to further explore the compensatory mechanisms involved in feed forward responses.

Introduction

Maintenance of homeostasis in the human body usually involves negative and positive feedback systems, well-documented regulatory loops that restore balance in response to a stimulus. Unlike negative and positive feedback systems, a third homeostatic control mechanism, feedforward regulation, responds to an external anticipatory cue prior to a change in the internal environment (Romanovsky, 2014). Thus, feedforward systems anticipate changes in a regulated variable, such as internal body temperature, improve the speed of the body's homeostatic responses, and minimize fluctuations in the level of the variable being regulated – that is, it reduces the amount of deviation from the set point (Hughson, 2003).

Investigating the presence of feedforward regulation in humans immediately prior to exercise is of interest to current research. All types of human movement, no matter the mode, duration, intensity, or pattern, require an expenditure of energy above homeostatic resting values (Burton *et al.,* 2004). Most of this energy will be provided to working muscles through the use of oxygen, supplied by the cardiovascular and respiratory systems (Burton *et al.,* 2004). Sympathetic signals to the heart increases heart rate to send more blood to the contracting and metabolically active muscles (Asmussen, 1981). While physiological changes are well documented during exercise, there is very little published research available that includes systematic measurements during the transition from rest to the time when exercise is anticipated but has not yet commenced.

The effectiveness of feedforward mechanisms is shown in a study conducted by Romanovsky (2014) demonstrates that thermoregulatory, non-hairy skin assesses possible drops in local temperature and sends pertinent thermal information as feedforward signals to the brain to provoke various behaviors prior to exposure. These heat-regulating behaviors thus act to slightly increase the body's temperature prior to a change in the environment in order to minimize drastic drops in body temperature as a result of the exposure (Kanosue *et al.*, 2010). Therefore, the seemingly subtle ability of the body to anticipate environmental stressors can be quantified and measured.

There is growing evidence that the perceptual-cognitive skill of anticipation is a fundamental control and performance variable within the domain of human performance. The ability to accurately anticipate and predict forthcoming actions and their physiologic effects has been shown to pertain to both cognitive and motor performance, such as during exercise (Land, 2016). An aspect of anticipation includes priming, a nonconscious form of human memory concerned with perceptual identification of words, objects, and actions. Priming activates particular representations or associations in memory just before carrying out an action or task (Tulving *et al.*, 1990).

The three physiological measurements used to observe the body's anticipatory response to exercise in our study were heart rate, blood pressure, and skin conductance, also known as Electrodermal Activity (EDA). A study conducted by Seifert *et al.* (2013) studied physiological responses during the anticipation and experience of pain, finding similar sympathetic activation, including EDA, during both periods. EDA is obtained to assess the influence of the sympathetic nervous system in the innervation of sweat glands (Boettger *et al.*, 2010). Additionally, a study published in the Journal of Biological Psychology and conducted by Waugh *et al.* (2010) showed comparable increases in heart rate and blood pressure between participants anticipating a stressor, and those recovering from the stressor. Knowing that these three physiological variables had potential to deviate from baseline during an anticipatory period, a survey designed to prime participants for exercise as well as an exercise routine to be performed were used to evoke varying effects on homeostasis in this study.

Prominent differences in resting heart rate and blood pressure are seen in sedentary individuals and those who exercise consistently. These differences are seen because the bodies of individuals who consistently exercise experience the homeostatic fluctuations that accompany physical exertion more regularly. These differences were measured in a study by Lee *et al.* (2014) which observed the sweat onset time, sweat rate, and skin temperature of 20 sedentary controls and 16 long-distance runners before and during exercise. The study concluded that there was a significant correlation between sweat onset time, directly activated sweat rate, and sweat output per gland, suggesting that long distance runners have a greater upregulation of sweating responses than those who are sedentary. As sweating is a physiological response that brings the body back towards homeostasis, this finding suggests that trained athletes have a faster and stronger feedforward response.

To further explore the relationship between an individual's fitness level and the magnitude of physiological changes that occur in anticipation of exercise, deviations from baseline in heart rate, blood pressure, and EDA were compared between groups of varying activity levels. It was hypothesized that similar physiological deviations from homeostasis would be observed in the *anticipation* of exercise as compared to subsequent exercise in all participants regardless of fitness level due to feedforward mechanisms. The degree of deviation from baseline measurements observed in the three chosen variables would serve as an indicator of the body's ability to minimize homeostatic fluctuations by preparing in advance. Additionally, it was hypothesized that physically fit individuals would demonstrate a heightened and more efficient anticipatory feedforward response to prevent dramatic physiologic deviations than individuals who do not maintain a consistent exercise routine. Low variability between the anticipatory and post-exercise period measurements would indicate a more efficient feedforward mechanism, while greater variability would indicate a standard feedforward response.

Materials

The three physiological variables measured were heart rate, blood pressure, and EDA. Heart rate, measured in beats per minute (bpm), and blood pressure, measured in mmHg, were collected using the OMRON 10 series + Blood Pressure Monitor (Model BP791, OMRON Corporation, Hoffman Estates, IL). EDA, measured in microsiemens (μS), was collected using an Electrode Finger Transducer (SS3LA, BIOPAC Systems, Inc., Goleta, CA) and two BSL EDA finger electrodes (Model: SS3LA) with Isotonic Recording Electrode Gel (GEL101, BIOPAC Systems, Inc., Goleta, CA). The gel was removed from the electrodes using a curity cotton tipped applicator (SN: 8884541400, Medtronic, Minneapolis, MN).

Measurement collection and data analyzation was performed using the BIOPAC Student Laboratory System (BSL 4.0 Software; MP36 hardware, BIOPAC Systems, Inc., Goleta, CA, USA) on a Dell Computer (Windows 7 system, Microsoft Corporation, Redmond, WA). The BIOPAC Student Lab Manual (MANBSL4, BIOPAC Systems, Inc., Goleta, CA, USA) was used as a reference for equipment usage and handling directions during the experiments.

Methods

Participants

Healthy volunteers were randomly selected from a pool of students enrolled in Physiology 435 at the University of Wisconsin-Madison, as well as teaching assistants of the course, during the Spring 2018 semester. Participants received no compensation for their time. A total of 30 participants (6 male and 24 female) were included in the study with an age range of 20-33 years. Participant exercise regimens ranged from 0 - 4+ days of exercise per week. The types of exercises that the participants engaged in were cardio and strength training.

Prior to participation in the study, written consent was obtained from the volunteers. This consent form contained general information pertaining to the purpose of the study and any risks the participant would possibly encounter. Due to the physical exertion component of this study, participants were informed that their involvement was voluntary and that they could stop at any time.

Experimental Procedure

Following the consent process, the participant was led into a room with three of the researchers. The door was shut to prevent outside distractions or stimuli. The participant was seated in an upright, relaxed position, with feet squarely in front of him or her on the floor. Conductive gel was applied to two electrodes attached to the Biopac Systems Electrode Finger Transducer, which researchers wrapped around the participant's non-dominant index and middle finger to measure EDA. The OMRON 10 series + Blood Pressure Monitor was then wrapped around the participant's non-dominant bicep to measure both heart rate and blood pressure. The participant was asked to not speak while the measurements were taken, and the computer and blood pressure monitor was turned away so that they could not observe their measurements.The three physiological measurements were then collected over a period of 30 seconds as a baseline control.

After these resting measurements were obtained and recorded, the participant remained connected to both the blood pressure and heart rate monitors as well as the finger transducer. The researchers gave a brief overview (Appendix A) and timeline (Figure 1) of the experiment, including a descriptions of the 10 standard style pushups, 20 jumping jacks, and 30-second wall that they would complete (Appendix B). The participant was told that the average person is able to complete these exercises in 55 seconds, and instructed to try to beat this time. While this is not true, as it usually takes closer to two minutes to complete this exercise, this instruction was given as a motivation to the participants to fully exert themselves in attempts to compete with the "average" time and perform to the best of their abilities. Following these instructions, a thorough survey inquiring about basic demographic information and physical fitness level was administered (Appendix C). This survey provided the researchers with information regarding the individual's perceived fitness and exercise familiarity by asking participants to quantitatively answer questions about their exercise habits and fitness level. These answers allowed the researchers to group participants later on when analyzing the data. The exercise-related questions in the survey, combined with the study overview given by the researcher, acted as a primer to induce a physiological feedforward response in anticipation of exercise that the researcher informed the participant they would complete following the survey. After completion of the survey, the second set of vital measurements were obtained following the above procedure to measure the participant's physiological response during anticipation of exercise.

After the anticipatory measurements were collected, the finger transducer and blood pressure monitor were then removed from the participant by the investigator. Once removed, the participant was asked to proceed in completing the previously described exercise under moderate intensity as outlined in Appendix B. After completion, the blood pressure monitor and finger transducer were placed back on the participant, and their heart rate, blood pressure, and EDA were recorded in an identical manner to the first two measurements. This third set of measurements was considered the post-exercise vitals.

Data Analysis

To determine significance between the baseline control measurements and the anticipatory response measurements, changes in heart rate, blood pressure, and EDA were compared. The same was done for determining differences between each participant's baseline and final measurements, and anticipatory and final measurements.

After all participants completed the experiment, the maximum difference from baseline for each variable during the two experimental periods was calculated and an average of each change difference was recorded. The participants were grouped into three cohorts based on their survey response to exercising “0-1 times per week,” “2-3 times per week”, or “4 or more times per week.” A series of ANOVA tests were utilized to compare the anticipatory and exercise period measurements to the baseline measurements between the three groups. The results of the ANOVA tests and corresponding p-values were used to identify the effects, if any, that anticipation of exercise had on physiological responses. A p-value of ≤ 0.05 was considered statistically significant.

EDA data was collected by recording the average conductance over a time period of 2 seconds that encompasses the highest peak during the periods of anticipation and exercise.

Negative Control

Participants’ resting levels for heart rate (bpm), blood pressure (mmHg), and EDA (μS) were measured and recorded following the procedure outlined above. In order to ensure resting levels, these measurements were recorded with the participant seated in a relaxed position prior to being informed about the details of the experiment or completing any exercise. Table 1 displays resting heart rate and blood pressure, and figure 2 displays resting EDA data obtained during the pilot study. Each participant’s baseline measurements served as his or her negative control data, providing the individual’s vitals prior to anticipation, thus illustrating that external conditions were not affecting the desired measurements.

Positive Control

In a pilot study, the changes in heart rate, blood pressure, and EDA due to a stressor could all be measured with biopac devices, as portrayed in Table 1 and Figures 2 and 3. Figure 2 displays resting EDA on a participant prior to exercise, collected as outlined by the above procedure. The participant completed the exercises according to the procedure to create a physiologic change from the baseline state, and the consequent measurements were recorded with the participant seated after exercising in an identical manner as the baseline measurements. Resting baseline heart rate was 71 beats per minute (bpm), and resting blood pressure was 124/92 mmHg. The post-exercise physiological changes are depicted in Figure 3, which shows a spike in EDA, and Table 1, which shows heart rate and blood pressure deviations from baseline. Baseline pulse was 71 beats per minute (bpm) and blood pressure was 124/92 mmHg. Following the exercise, pulse was 99 bpm and blood pressure was 153/101 mmHg. Evidence of this positive control data shows that measurable change is attainable in the physiological tests, as was expected that all three of these variables increase as a result of exercise. The pilot study demonstrated the validity of the control measurements and the effectiveness of the researchers to utilize the equipment properly.

Results

Subject Characteristics

A total of 30 participant results were used in this study (6 males and 24 females, mean age(s.d.) = 21.6(2.3)). The majority of the participants were enrolled in Physiology 435 at the University of Wisconsin-Madison, and the remaining participants were Physiology 435 Teaching

Assistants. Prior to participating, each subject signed a consent form and were assigned a subject number to ensure confidentiality.

Survey Results

Following the consenting process, participants were asked to self-report their perceived fitness level and weekly exercise routine. Figure 4 shows the distribution of participants that performed cardiac exercise for varying durations of time per week. Figure 5 similarly shows the distribution of participants that performed anaerobic exercise, such as lifting weights, for varying durations of time per week. Evidenced by Figure 6, the majority of participants (80%) identified themselves as "physically fit."

Physiological Data Results

A series of ANOVA tests with a p-value of $p<.05$ were used to compare the deviation from baseline to the anticipatory phase and the exercise phase for each of the three physiological measures.

Heart Rate

The average change in heart rate between baseline and anticipation of exercise for the group of participants that exercised zero to one times per week was 5.44 bpm. The average change for the group that exercised between two to three times per week was 5.08 bpm. The average change for the group that exercised four or more times per week 8.38 bpm. The p-value comparing these three groups' changes was 0.8230 and therefore insignificant.

The average change in heart rate between baseline and after exercising for the group of participants that exercised zero to one times per week was 11.78 bpm. The average change for the group that exercised between two to three times per week was 14.46 bpm. The average change for the group that exercised four or more times per week 6.88 bpm. The p-value comparing these three groups' changes was 0.4050 and therefore insignificant.

The average heart rate measurements for each of the three groups throughout the study can be seen in Figure 7. The average heart rate changes of each of the three groups between each of the different intervals within the study can be seen in Figure 8.

ElectroDermal Activity

The average change in EDA between baseline and anticipation of exercise for the group of participants that exercised zero to one times per week was 1.04 µS. The average change for the group that exercised between two to three times per week was 1.35 µS. The average change for the group that exercised four or more times per week 1.31 µS. The p-value comparing these three groups' changes was 0.888 and therefore insignificant.

The average change in EDA between baseline and post-exercising for the group of participants that exercised zero to one times per week was 1.12 µS. The average change for the group that exercised between two to three times per week was 2.19 µS. The average change for the group that exercised four or more times per week -0.104 µS. The p-value comparing these three groups' changes was 0.0737 and therefore insignificant.

The average EDA of each of the three groups across the study can be seen in Figure 9. The average EDA changes seen in each of the three groups between each interval of the study can be observed in Figure 10.

Diastolic Blood Pressure

The average diastolic blood pressure change between baseline and anticipation of exercise for the group of participants that exercised zero to one times per week was 3.33 mmHg.

The average change for the group that exercised between two to three times per week was 0.23 mmHg. The average change for the group that exercised four or more times per week 2.5 mmHg. The p-value comparing these three groups' changes was 0.597 and, therefore, insignificant.

The average diastolic blood pressure change between baseline and after exercising for the group of participants that exercised zero to one times per week was 3.0 mmHg. The average change for the group that exercised between two to three times per week was 3.0 mmHg. The average change for the group that exercised four or more times per week 4.875 mmHg. The p-value comparing these three groups' changes was 0.8693 and therefore insignificant.

The average DBP measurements for the three groups during their baseline, pre-exercise, and post-exercise recordings can be seen in Figure 11. The average DBP changes for each of these three groups between baseline and pre-exercise, baseline and post-exercise, and pre-exercise and post-exercise can be seen in Figures 13-15, respectively.

Systolic Blood Pressure

The average systolic blood pressure change between baseline and anticipation of exercise for the group of participants that exercised zero to one times per week was 2.0 mmHg. The average change for the group that exercised between two to three times per week was 5.38 mmHg. The average change for the group that exercised four or more times per week 0.0 mmHg. The p-value comparing these three groups' changes was 0.4454 and therefore insignificant.

The average systolic blood pressure change between baseline and after exercising for the group of participants that exercised zero to one times per week was 16.44 mmHg. The average change for the group that exercised between two to three times per week was 15.54 mmHg. The average change for the group that exercised four or more times per week 3.60 mmHg. The p-value comparing these three groups' changes was 0.3491 and therefore insignificant.

The average SBP measurements for the three groups during their baseline, pre-exercise, and post-exercise recordings can be seen in Figure 12. The average SBP changes for each of these three groups between baseline and pre-exercise, baseline and post-exercise, and pre-exercise and post-exercise can be seen in Figures 13-15, respectively.

Discussion

After determining that the collected physiological data was statistically insignificant, the proposed hypothesis that similar physiological deviations from homeostasis due to feedforward mechanisms during the anticipatory phase and during the exercise phase was rejected. It was concluded that a variety of factors may have influenced the validity of the results. These factors resulted from equipment sensitivity issues, participants' predetermined expectations of the study, and slight inconsistencies between the researchers.

The overall objective of the study was to determine if a physical change in response to anticipation of exercise could be detected that was comparable to the physical change produced during exercise. The physiological measurements of heart rate, blood pressure, and EDA showed insignificant changes, as calculated from baseline, during anticipation and exercise. While there were no significant p-values ($p<0.05$) between treatment groups, the general trends of some of the the data averages demonstrated a few potential relationships that could be further investigated in a study with a larger sample size. For example, some of the changes between the three groups using the EDA data were approaching significance with p-values of 0.0737 and 0.0611 when looking at the EDA average changes between baseline and post-exercise and pre and post-exercise, respectively. Perhaps with a larger sample size, we would be able to determine whether those that exercise more frequently have a significantly different ability to regulate their EDA and show less of a change similar to that seen in our results and in Figure 10.

The second objective of the study was to determine whether individuals who consistently exercise exhibit more comparable physiological changes between anticipation and actual exercise than those who do not exercise regularly. Study participants did not exhibit group-specific anticipatory responses to exercise despite a significant difference in scores on the self-reported survey. The data implies that those who had a higher perceived fitness level did not exhibit the expected anticipatory response. It is possible that the participants already had an increased rate of cardiac output before baseline measurements were taken, due to the fact that they had just walked into the room (mild exercise) and sat down. A future study could account for more time between walking into the room and taking baseline measurement, for blood pressure to return to a normal level. Additional research could also be done to investigate the onset and duration of anticipatory responses, giving more clarity on whether our actions to incite the anticipatory response in our participants was adequate, as well as the amount of time we gave their bodies to produce this response. It is also possible that the participants who do not exercise regularly had more anxiety when told that they must exercise, which can increase cardiac output, and this could have been due to nerves rather than their body's natural feedforward response. Although we did not explicitly analyze or group individuals based on their responses to their levels of anxiety on our initial survey within our results, this could be further reviewed in a future study taking into account anxiety's impact on anticipatory responses to exercise. Our grouping of individuals based on their self-reported exercise schedule may have played a role in our lack of significance, as well. Our decision to group participants into the 0-1 days per week, 2-3 days per week, and 4 or more days per week groups was done to attempt to maintain three equal groups given the participants we had. It would be interesting to see further research conducted to determine the extent of weekly exercise required to see noticeable physiological anticipatory response changes, and using this we would be able to more accurately select our groups.

There were multiple external factors recognized that may have affected our results due to random or systematic errors. After conducting the research following the outlined methods, it was determined that some improvements in lab equipment, data collection, and analytic methods would result in a more valid future study. It is possible that the minor differences in how each researcher performed the experiment or behaved with participants could have contributed to changes in outcome. For instance, the amount of gel added to the EDA device may have varied slightly with each researcher, and affected the results of EDA.

Future research on feedforward anticipatory mechanisms can be improved to limit the number of external sources of error, including the regular testing of experimental equipment to ensure accurate data collection, thereby improving the overall accuracy of the study. This study could also be performed using other available physiological measurements, such as respiratory rate, to allow for increased data collection and comparison. Additional research can assess participant fitness level using a methodology that does not include self-report, thus limiting the introduction of bias. Requiring the same researchers to conduct the study each time, rather than switching off, would limit interobserver errors. Conducting an interobserver error test in future studies would allow the researchers to see the different interpretations of each observer. The test could show the researchers if there was any difference in the results of the participants based on who the observer was. Finally, increasing the duration of exercise to longer than one minute and including different forms of exercise taking into account both aerobic and anaerobic activities may result in a more realistic physiological response.

Figures and Tables:

Table 1: Physiological measurements collected during a resting period, anticipatory period, and post-exercise period (Pilot Study).

Experimental Period	Blood Pressure (mmHg)	Heart Rate (bpm)	EDA (µS/sec)
Resting	124/92	71	6.827
Anticipatory	149/100	81	9.023
Post-Exercise	153/101	99	10.86

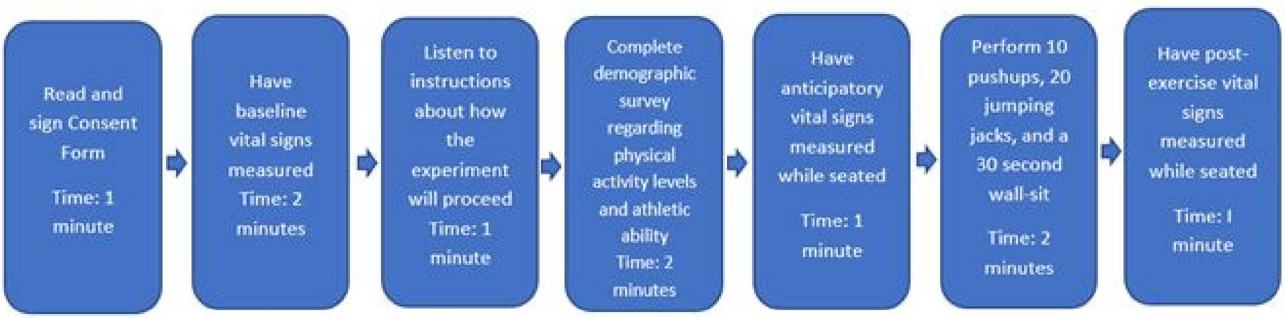

Figure 1: Experimental Timeline. An overview of expected time per step during the experiment (9 minutes in total). Consent from the participant was obtained prior to the baseline measurements, which occured while the subject was connected to both of the devices that measured physiological responses before being informed of the expected exercise component. This acted as a negative control because no deviation from homeostasis was expected. The researcher then read the script out loud that informed the participant that after completion of a physical fitness survey, they would be performing three specific exercises. The participant then filled out the survey which asked questions related to fitness level, intended to induce anticipation of stress. A second set of measurements were taken to assess the feedforward anticipatory response. The participant then completed three exercises shown to create deviations from baseline. A final set of measurements was taken following exercise, serving as the positive control.

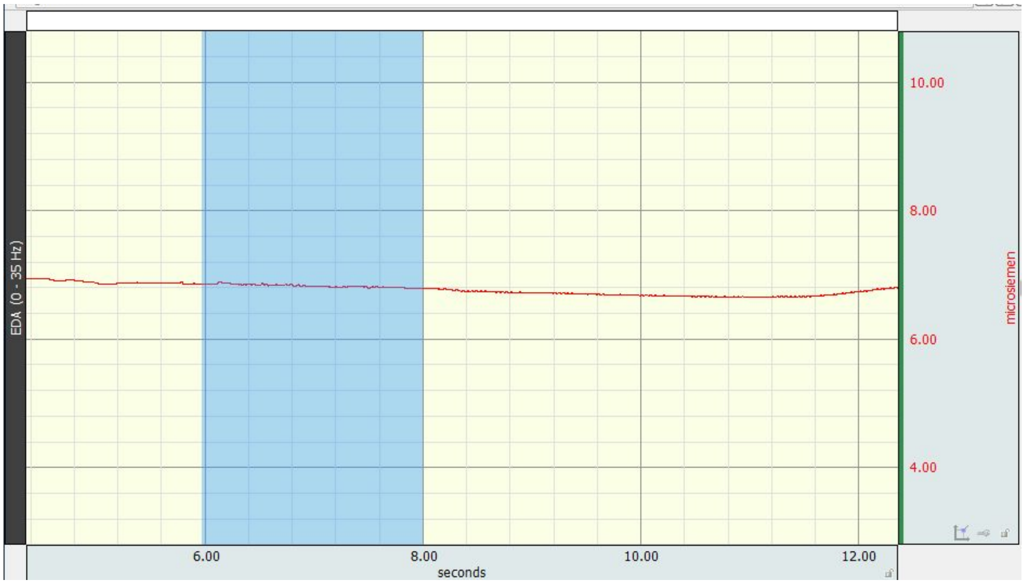

Figure 2: EDA resting baseline data. This figure shows the EDA of an individual averaged over the two second interval encompassing the peak of conductance (6.83 μS) prior to the anticipatory and exercise periods.

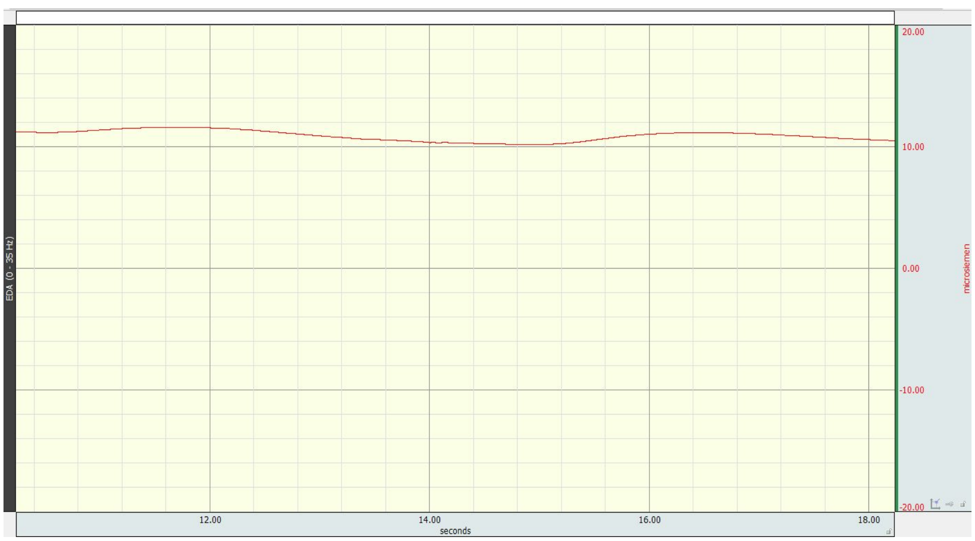

Figure 3: EDA data after exercise. This figure shows the elevated EDA of an individual averaged over the two second interval encompassing the peak of conductance (10.86 μS) following physical activity.

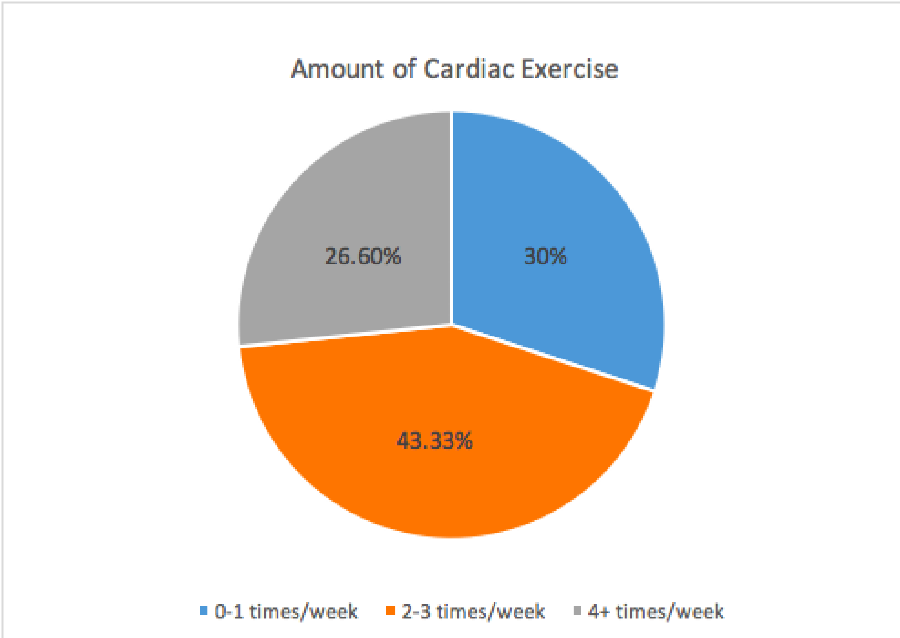

Figure 4: This graph displays the percentage of the participants (n=30) self-reporting duration of cardiac exercise (0-1 times/week, 2-3 times/week, 4+ times/week).

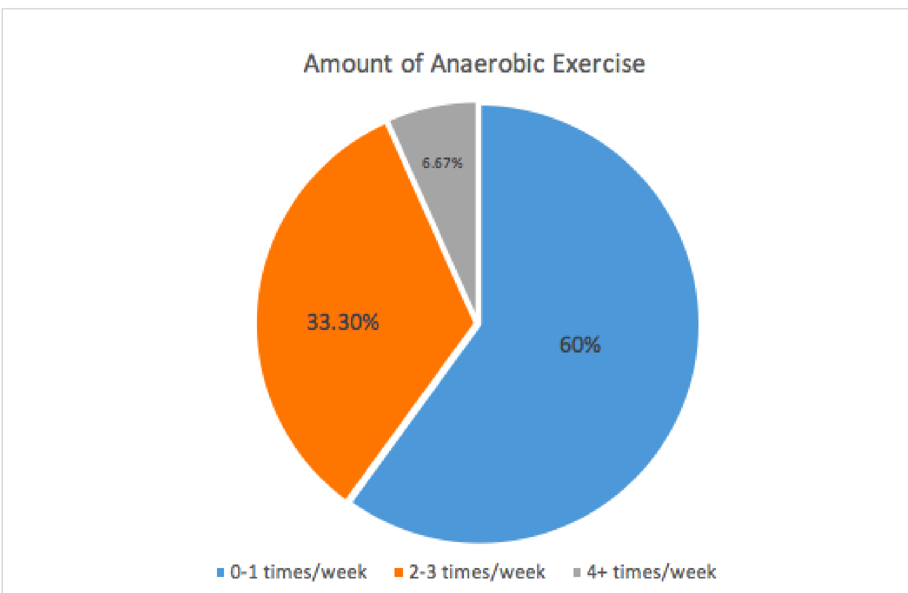

Figure 5: This graph displays the percentage of the participants (n=30) self-reporting duration of anaerobic exercise (0-1 times/week, 2-3 times/week, 4+ times/week).

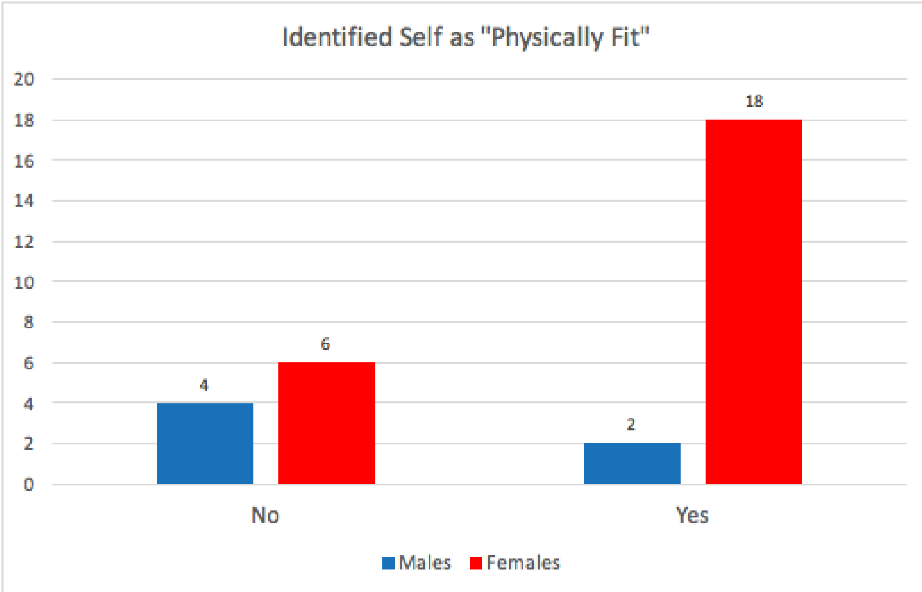

Figure 6: This graph displays the results of the self identification of participants (n=30) as “physically fit.” These groups are further split based upon the gender identification of the participant.

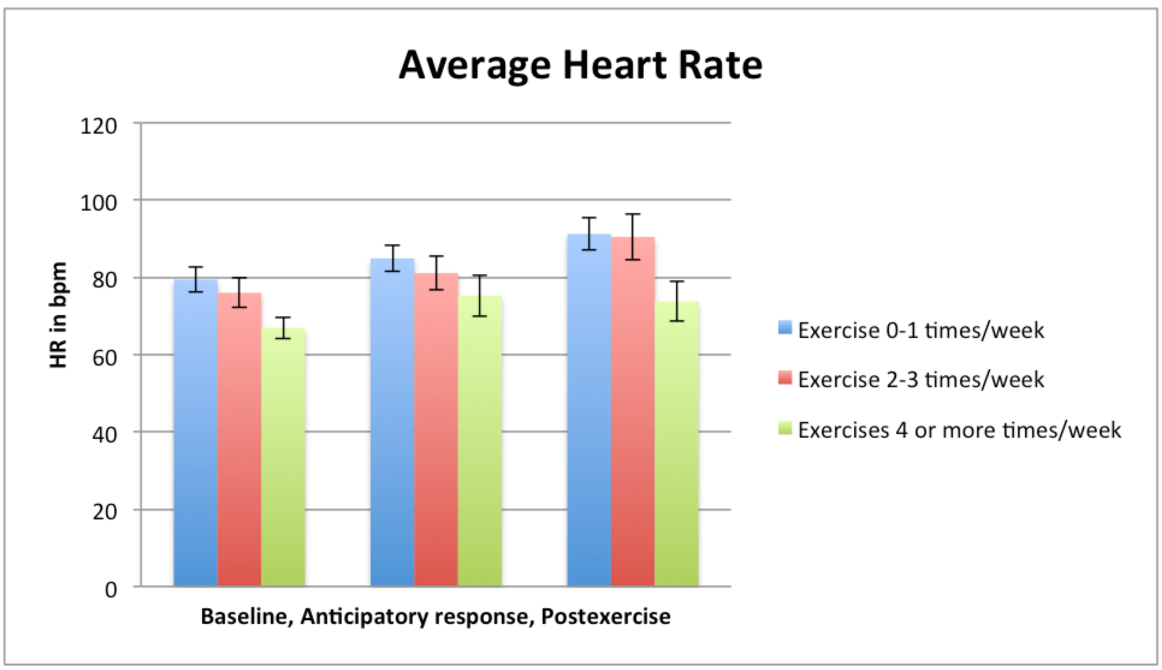

Figure 7: The graph displays the average heart rate (bpm) at each stage of the experiment: baseline, pre-exercise (anticipatory response), and post-exercise. That data of each measurement point is further broken down relative to the fitness level of the participant.

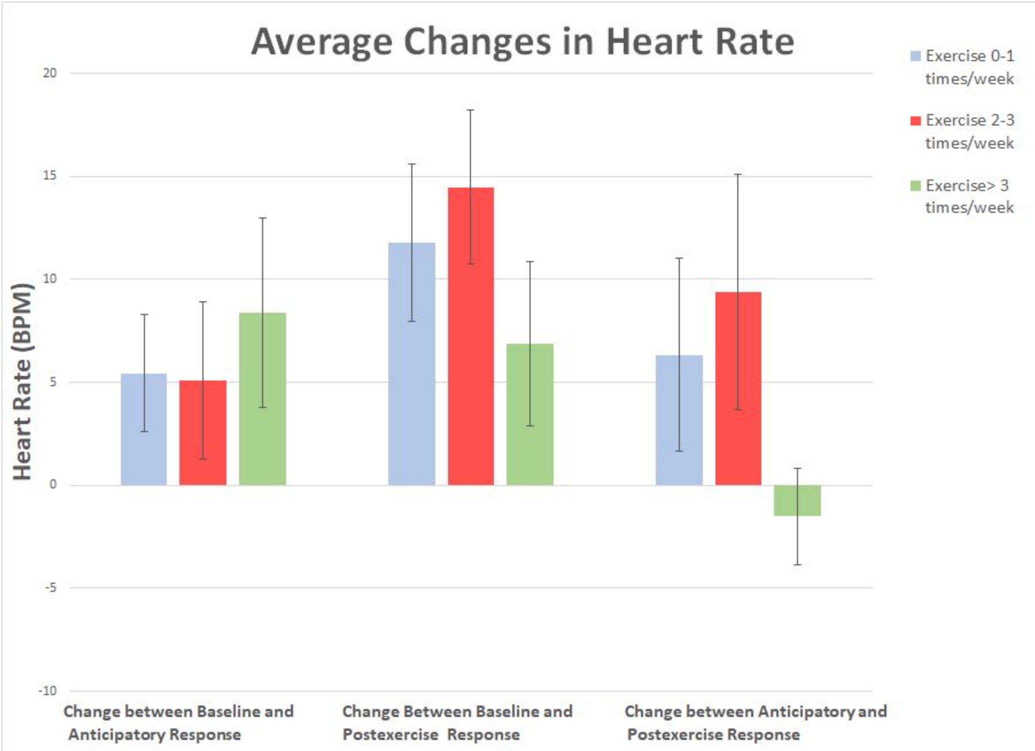

Figure 8: This graph displays the average change in heart rate (bpm) for each change in stage of exercise (between baseline and anticipatory, baseline and post-exercise, and anticipatory and post-exercise). Each type of fitness level group is represented by the colored bars.

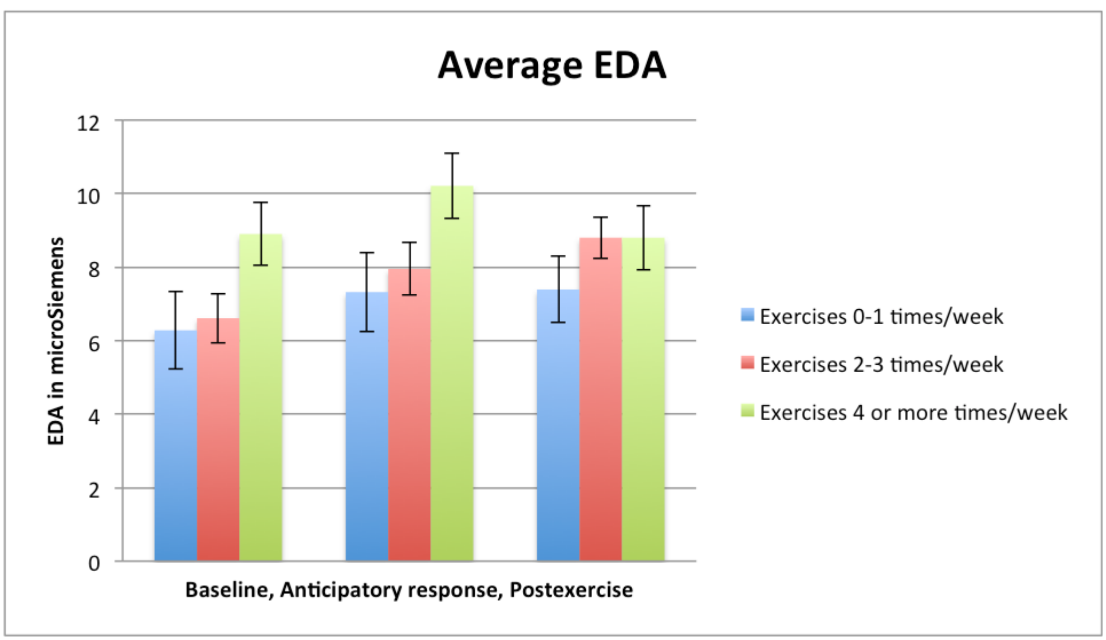

Figure 9: The graph displays the changes in EDA (μS) in response to the stage of exercise - baseline, anticipatory, or postexercise. The comparison between athletes, intermediate athletes, and nonathletes is portrayed by the colored bars.

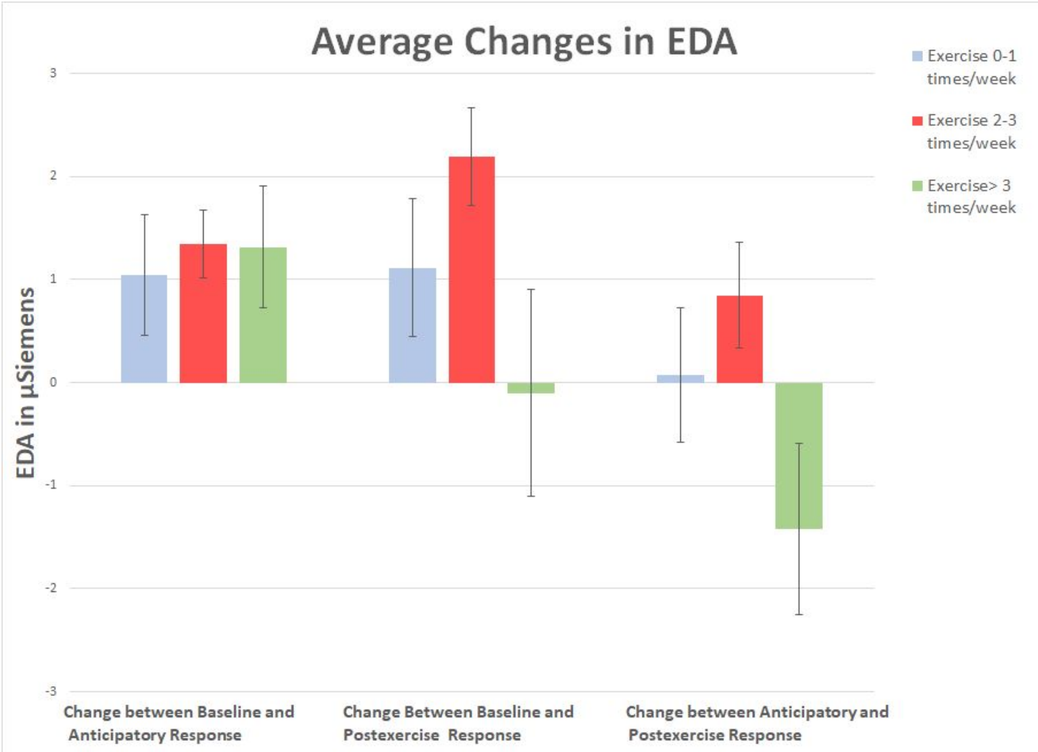

Figure 10: The graph displays the change of EDA (µS) between the baseline to anticipation, the baseline to post-exercise, and the anticipation to postexercise. The three different fitness levels are compared to each other during each stage.

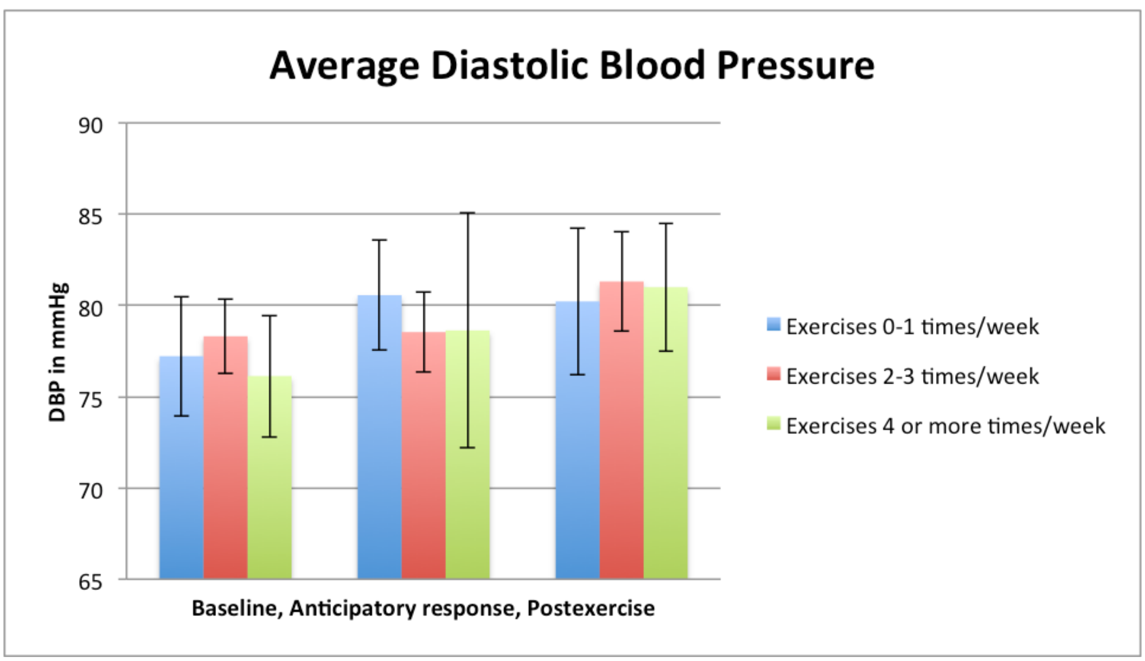

Figure 11: This graph displays the average diastolic blood pressure (DBP) in mmHg, in response to each stage of exercise - baseline, anticipatory, and postexercise. The nonathletes, intermediate athletes, and athletes are presented in blue, red, and green, respectively. Standard error bars are included.

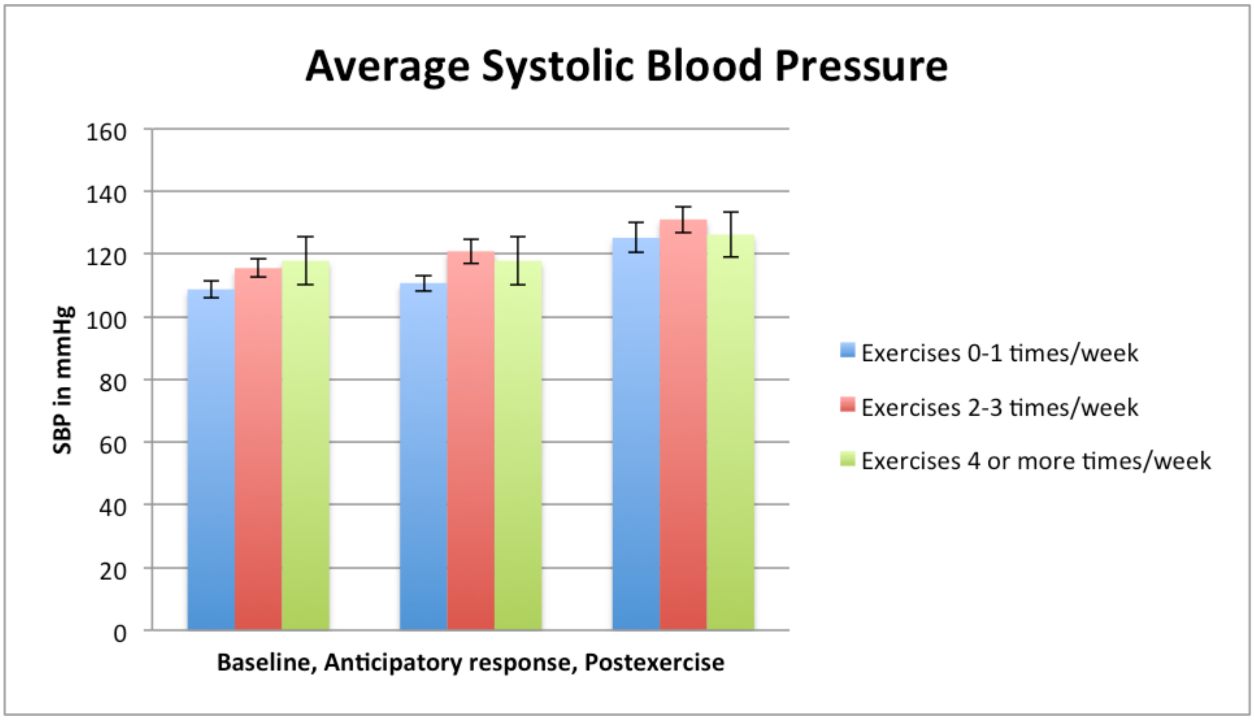

Figure 12: This graph displays the average systolic blood pressure in mmHg at the three stages of the experiment: baseline, anticipatory, and postexercise. The different colored bars signify the averages of the three cohorts based on their time spent exercising per week.

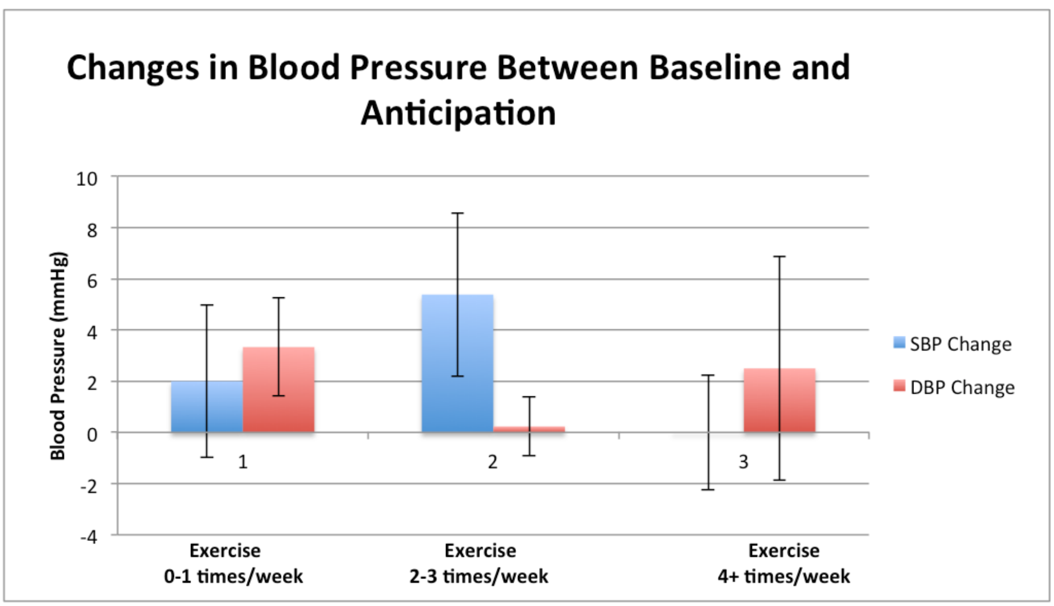

Figure 13: The graph displays systolic and diastolic blood pressure in mmHg versus the three different groups of fitness levels, in comparing between baseline and anticipation. Standard error bars are included. Systolic blood pressure appears to increase with increasing fitness level, while diastolic blood pressure appears not to have a correlation with fitness level.

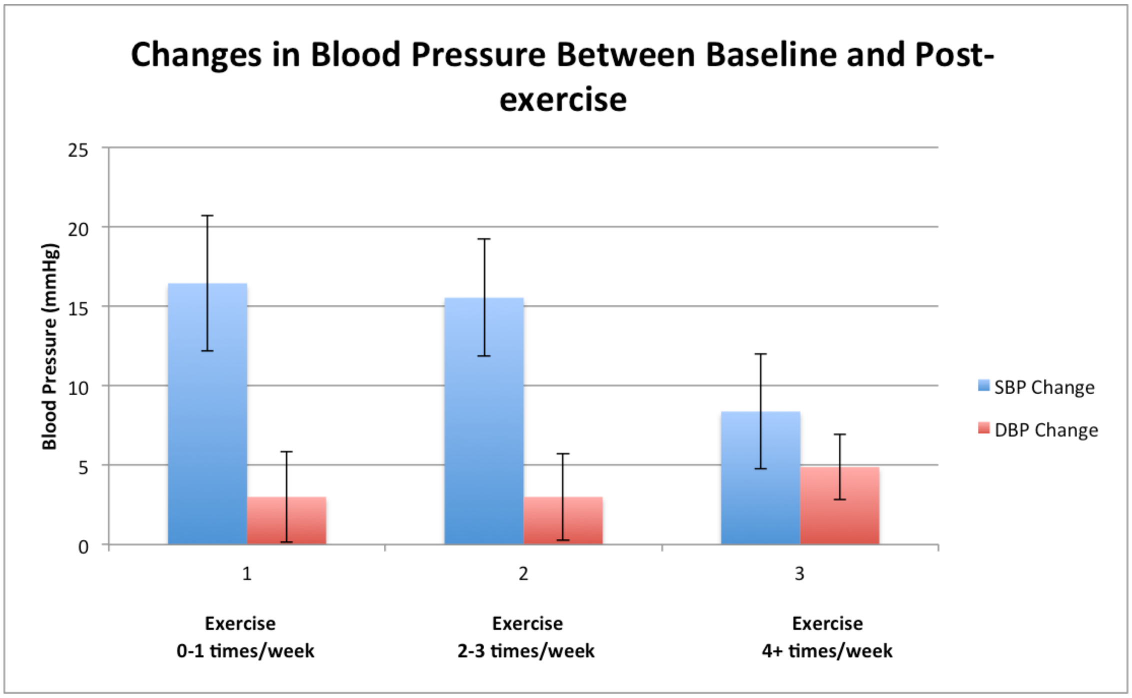

Figure 14: The graph displays average systolic and diastolic blood pressure in mmHg versus the three different groups of fitness levels, in comparing blood pressure between baseline and post-exercise. Standard error bars are included.

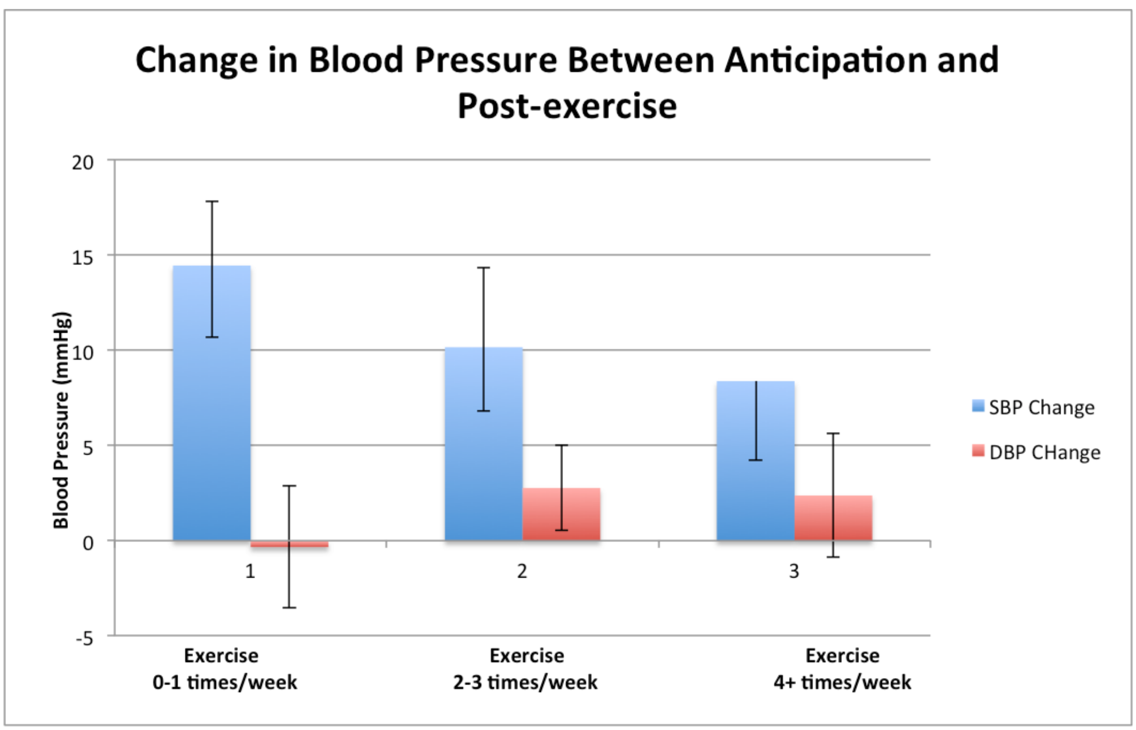

Figure 15: The graph displays systolic and diastolic blood pressure in mmHg versus the three different groups of fitness levels, in comparing between anticipation and post-exercise. Standard error bars are included.

References

Asmussen E (1981). Similarities and dissimilarities between static and dynamic exercise. *Circ Res* **48,** 3-10.

Boettger S, Puta C, Yeragani V, Donath L, Mueller H, Gabriel H & Baer K (2010). Heart rate variability, QT variability, and electrodermal activity during exercise. *Med Sci Sports Exerc* **42**, 443-448.

Burton D, Stokes K, & Hall G (2004). Physiological effects of exercise. *BJA Educ* **4**, 185-188.

Hughson R (2003). Regulation of blood flow at the onset of exercise by feed forward and feedback mechanisms. *Can J Appl Physiol* **28**, 774-787.

Kanosue K, Crawshaw L, Nagashima K & Yoda T (2010). Concepts to utilize in describing thermoregulation and neurophysiological evidence for how the system works. *Eur J Appl Physiol* **109**, 5-11.

Land, W (2016). Action effects and task knowledge: the influence of anticipatory priming on the identification of task-related stimuli in experts. *PLoS One* **11**, 15-28.

Lee J, Kim T, Min Y & Yang H (2014). Long Distance Runners Present Upregulated Sweating Responses than Sedentary Counterparts. *PLoS One* **9,** 93-97.

Romanovsky A (2014). Skin temperature: its role in thermoregulation. *Acta Physiol* **210**, 498-507.

Seifert F, Schuberth N, De Col R, Peltz E, Nickel F, & Maihöfner C (2013). Brain activity during sympathetic response in anticipation and experience of pain. *Hum Brain Mapp* **34**, 1768-1782.

Tulving E & Schacter D (1990). Priming and human memory systems. *Science* **247**, 301-306.

Waugh C, Panage S, Mendes W, & Gotlib I (2010). Cardiovascular and affective recovery from anticipatory threat. *Biol Psychol* **84**, 169-175.

Acknowledgements

We would like to thank Dr. Andrew Lokuta, the teaching assistants, the peer learning volunteers, and study participants for their time dedicated to and help with the study.

Appendix A

Experimental Script

Begin by requesting that the participant does not speak while measurements are being taken in order to avoid any confounding variables.

After taking baseline measurement: "After you complete this survey, you are going to perform 10 pushups, 20 jumping jacks, and a 30 second wall sit. Most people complete the physical exercise in under 55 seconds - try to beat this time."

After they complete the survey: "Thank you for completing the survey, we're now going to take your measurement again and then you will perform the exercise."

Appendix B

Description of Exercise Techniques

Push-Up: Place your hands on the floor so they're slightly outside shoulder-width. Spread your fingers slightly out and have them pointed forward. Raise up onto your toes so that all of your body weight is on your hands and feet. Contract your abdominals to keep your torso in a straight line and prevent arching your back or pointing your bottom in the air. Bend your elbows and lower your chest down toward the floor. Once your elbows bend slightly beyond 90 degrees, push off the floor and extend them so that you return to starting position. Repeat 10 times.

Jumping Jack: Stand straight with your feet together and hands by your sides. Jump up, spread your feet and bring both hands together above your head. When landing, keep your knees slightly bent and land softly on the balls of your feet. Jump again and return to the starting position. Repeat 20 times.

Wall Sit: Start with your back against a wall with your feet shoulder width and about two feet from the wall. Slowly slide your back down the wall until your thighs are parallel to the ground. Adjust your feet if you need to so that your knees are directly above your ankles. Keep your back flat against the wall and hold the position for 30 seconds.

Appendix C

Participant Survey

How old are you?

On a scale of 1-10, how comfortable are you in general social situations? **PLEASE CIRCLE** - 1 being extremely uncomfortable, 10 being extremely comfortable.

1 2 3 4 5 6 7 8 9 10

On a scale of 1-10, how comfortable are you in performing physical exercise (e.g., running, playing a sport) in front of others? **PLEASE CIRCLE**

1 2 3 4 5 6 7 8 9 10

Do you consider yourself "physically fit"? **PLEASE CIRCLE** YES or NO.

On average, how often do you perform cardio exercises (e.g. biking, running, swimming, etc) in a week? **PLEASE CIRCLE** the answer that best reflects your level of activity.

- 0-1 times a week
- 2-3 times a week
- 4 or more times a week

TYPICAL LENGTH OF EACH CARDIO WORKOUT (**Hours:minutes**):

____

On average, how often do you perform anaerobic exercises (e.g. weight lifting) in a week? **PLEASE CIRCLE** the answer that best reflects your level of activity?

- 0-1 times a week
- 2-3 times a week
- 4 or more times a week

TYPICAL LENGTH OF EACH ANAEROBIC WORKOUT (**Hours:minutes**):

____