Autonomic Nervous System Responses to an Acute Bout of Vinyasa Yoga

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Cardiovascular disease is the number one cause of death worldwide. Many behaviors, such as physical activity, influence cardiovascular health. Meeting physical activity guidelines is one method to improve health/and decrease disease risk, possibly due to changes in autonomic function. Vinyasa yoga has been found to be a form of moderate-intensity physical activity; however, autonomic and cardiovascular responses to this style of yoga have not been thoroughly

studied. **Purpose:** The purpose of this study is to examine the effect of a vinyasa yoga session on measures of autonomic nervous system function, including heart rate (HR), systolic blood pressure (SBP), and heart rate variability (HRV).

Methods: Eighteen subjects completed two separate laboratory visits that included baseline measurements, 60 minutes of vinyasa yoga or 60 minutes of viewing a documentary, 5 minute post condition measurements, desk work, and 65 minute post condition measurements. These measurements included SBP, HR, and HRV factors (standard deviation of normal-to-normal R-R intervals (SDNN), root mean square of successive differences (RMSSD), and high frequency (HF) HRV parameters), and a Standardized Subjective Exercise Experience Scale (SEES).

Results: SBP responses were significantly lower 5 minutes post yoga (-8.14 mmHg; p= 0.000) and not significantly lower 65 minutes post yoga (-2.76 mmHg; p=0.136) compared to the control. HR responses were significantly higher 5 (+10.49 bpm; p=0.000) and 65 minutes (+4.7 bpm; p=0.002) post yoga compared to the control. SDNN was significantly lower 5 (-0.24 ln; p=0.006) and 65 minutes (-0.14 ln; p=0.001) post yoga compared to the control. RMSSD was significantly lower 5 (-0.49 ln; p=0.000) and 65 minutes (-0.29 ln; p=0.000) post yoga compared to the control. HF was significantly lower 5 minutes (-0.51 log; 0.008) post yoga and not significantly lower 65 minutes (-0.26 log; p=0.209) post yoga compared to a control. Overall, of the three factors of the SEES, positive wellbeing significantly improved post yoga compared to the control (p=0.040), while psychological distress (p=0.399) and fatigue (p=0.714) did not show significant differences between conditions.

Conclusions: A vinyasa yoga session has immediate BP benefits in the absence of HR/HRV improvements. A more comprehensive assessment of autonomic function is recommended.

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1.0 Introduction

Cardiovascular disease (CVD) is an umbrella term that includes diseases of the heart and/or vasculature, veins and arteries, in the body.[1] According to the American Heart Association, CVD was the leading cause of death worldwide in 2019. In 2017, CVD caused 868,662 deaths in the U.S. alone, and between 2016 to 2017, $363.4 billion was spent in America on direct and indirect costs of CVD.[2] There is a strong inverse relationship between cardiovascular health and all-cause mortality, and this same strong inverse relationship is seen between cardiovascular health and CVD mortality.[3] CVD can be caused by many health factors and behaviors including smoking, diabetes, being overweight/obese, poor diet, high cholesterol levels, high blood pressure (BP) and physical inactivity.[1,2]

The most recent physical activity guidelines were published in 2018 by the U.S. Department of Health and Human Services. They state that American adults gain substantial health benefits from completing 150-300 minutes of moderate-intensity aerobic activity or 75 minutes of vigorous-intensity aerobic activity weekly. Additional health benefits can be observed from participating in muscle-strengthening activities that are at least of moderate intensity involving the major muscle groups of the body two or more days a week. Americans who meet these weekly guidelines are likely to see improvements in their cardiovascular health.[4] In 2018, only 24% of American adults met both the aerobic and muscle-strengthening guidelines.[2] Based on the current number of Americans meeting the physical activity guidelines,[2] the ability of physical activity to improve cardiovascular health,[4] and the strong inverse relationship between cardiovascular health and all-cause/CVD mortality,[3] we can infer that more Americans should be meeting the physical activity guidelines to improve their cardiovascular health and reduce their mortality risk.

There are a wide variety of exercise modes that one can choose to meet the ACSM physical activity guidelines such as walking, running, cycling, or circuit training. Another mode of exercise to consider may be yoga as millions of Americans are currently practicing it.[5] One type of yoga, vinyasa yoga, has recently been studied and was shown to be a form of exercise.[6] Vinyasa yoga is a type of yoga that links movement with breathing. Yoga postures within this practice are linked together one after another as a series that also includes traditional vinyasas between these series.[7] Vinyasa yoga may be considered a form of moderate intensity physical activity. A study conducted by Sherman et al., found the average metabolic equivalents (METs) of a vinyasa yoga session to be approximately 4 METs. This intensity falls within the METs range of moderate-intensity physical activity, which is 3.0-6.0 METs.[6] These findings and the current *Physical Activity Guidelines for Americans 2nd edition* support the idea that vinyasa yoga may have similar physiological effects as moderate-intensity exercise.

Some of the physiological adjustments that the human body makes during exercise to meet the changing demands of the body are adjustments in heart rate (HR) and BP. These changes to HR and BP are primarily due to cardiac autonomic regulation in the body.[8] Adjustments to HR and blood vessel diameter (i.e. BP changes) can be controlled by the autonomic nervous system (ANS) (part of the peripheral nervous system) which sends signals through efferent pathways to peripheral organs.[9,10,11] The signals sent to peripheral organs initiate a response and act to involuntarily regulate HR, BP, respiration rate, and digestion to maintain a stable internal environment in the body.[9,10,12] These variables are regulated by two major subdivisions of the ANS: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). Both of these subdivisions have afferent and efferent fibers that supply sensory information to the central nervous system (CNS) and produce motor functioning based on the CNS's response.[8]

Heart rate variability (HRV) is one way to measure this cardiac autonomic regulation in the body at any given time. HRV is defined as the time variation/fluctuation between heartbeats that occurs due to the influence of the two branches of the ANS.[13] ANS functioning, particularly the influence of the PNS, can be determined through this measure of HRV. The SNS and PNS influence the cardiovascular system at rest and during exercise, so observing the effects of these nervous system branches on the body may be a powerful tool in understanding the risk of CVD.[11] For example, a longitudinal prospective study with 9,744 participants that did not have CVD during their baseline assessment found HRV to have an inverse dose-response relationship with CVD in adults between the ages of 45-85 years old. The findings of this study demonstrate that greater HRV is associated with a lower risk of CVD.[14]

HRV changes during exercise and post-exercise. Similar to HR, HRV has a curvilinear response to exercise. During exercise, there is sympathetic activation and parasympathetic withdrawal causing reduced HRV.[8] Post-exercise, complete parasympathetic reactivation may take up to 48 hours depending on the intensity of the exercise session,[15] and HRV has been found to continually increase during the recovery phase of an exercise session.[16] A systematic review by Bernhard Grassler et al. established endurance training as an exercise mode that has been found to be an appropriate intervention to increase HRV and improve autonomic functioning. These authors also reviewed what they considered coordinative training that included martial arts and yoga. They concluded that there may be HRV benefits from training modes like yoga; however, more evidence is needed.[17] One specific study in this review by Pal et al. determined that BP, a potential cardiovascular risk factor also improved from a yoga intervention.[18]

Current research suggests that there are many health benefits from practicing yoga. Many studies have found yoga to improve different aspects of wellness like improving mental health,[19] sleep,[19] promoting healthy habits (better eating/physical activity habits[19,20,21] and weight loss[22]),

and managing stress.[19,21] Yoga has also been found to have a positive effect on people suffering from depression or anxiety disorders.[23] Yoga has many physical benefits as well including improving balance, strength, flexibility, and heart health.[24] A few studies have also shown that yoga is capable of altering the ANS.[25]

Previous studies that included Bikram and Hatha yoga interventions did not demonstrate a relationship between yoga and HRV,[26,27] but perhaps a more potent yoga stimulus is needed to see results comparable to exercise's ability to alter HRV.[17] Vinyasa yoga is a type of yoga that has been approximated as a form of aerobic exercise, and perhaps would show a different relationship to HRV, BP, and resting HR compared to other forms of yoga. It has not been thoroughly studied to see if there is a relationship between this type of yoga and functioning of the ANS; therefore, the purpose of this study is to expand our knowledge on the role of vinyasa yoga on changes in autonomic regulation of the cardiovascular system.

1.1 Specific Aims

1.1.1 Determine the effect of a vinyasa yoga session on autonomic regulation of the cardiovascular system.

a) Examine the effect of a vinyasa yoga session on heart rate, systolic blood pressure, and heart rate variability 5 minutes and 65 minutes after a yoga session.
    a. Hypothesis: Vinyasa yoga will increase heart rate and decrease systolic blood pressure and heart rate variability 5 minutes following a vinyasa yoga session. Sixty-five minutes following a vinyasa yoga session, heart rate and systolic

blood pressure will be lower than baseline measurements and heart rate variability will exceed baseline measurements.

1.1.2 Determine the effect of a control session on autonomic regulation of the cardiovascular system.

a) Examine the ANS effects on heart rate, systolic blood pressure, and heart rate variability 5 minutes and 65 minutes after a control session.
    a. Hypothesis: The control session will show no change in heart rate, systolic blood pressure, and heart rate variability 5 minutes and 65 minutes post session compared to baseline measurements.

1.1.3 Compare autonomic regulation of the cardiovascular system between a vinyasa yoga session and a control session.

a) 5 minutes post sessions
    i. Examine the differences in heart rate, systolic blood pressure, and heart rate variability following a vinyasa yoga session and a control session.
    ii. Hypothesis: Vinyasa yoga will elicit a higher heart rate and lower systolic blood pressure and heart rate variability response compared to a control session 5 minutes after each session.

a) 65 minutes post sessions

i. Examine the differences in heart rate, systolic blood pressure, and heart rate variability 65 minutes after a vinyasa yoga session and 65 minutes after a control session.

ii. Hypothesis: Vinyasa yoga will elicit a lower heart rate and systolic blood pressure and higher heart rate variability compared to a control session 65 minutes post session.

1.1.4 **Exploratory Aim:** Determine positive and negative changes in psychological responses to a vinyasa yoga and control session.

a) Examine the **positive and negative changes in psychological responses** following a vinyasa yoga session compared to baseline responses.
    a. Hypothesis: There will be improvements in p**sychological** responses following the vinyasa yoga session compared to baseline responses.

b) Examine the **positive and negative changes in psychological responses** following a control session compared to baseline responses.
    a. Hypothesis: There will be no change in responses following the control session compared to the baseline responses.

c) Compare the **positive and negative** differences in psychological responses between the vinyasa yoga and control sessions.
    a. Hypothesis: P**sychological** responses will improve following the vinyasa yoga session compared to the control session.

1.2 Significance

Currently, CVD is extremely prevalent worldwide accounting for more deaths than any other health conditions.[2] Considering that there is a strong inverse relationship between cardiovascular health and mortality,[3] something must be done to improve cardiovascular health. There are many ways to improve one's cardiovascular health, including meeting the ACSM Physical Activity Guidelines of 150-300 minutes of moderate-intensity aerobic activity or 75-minutes of vigorous-intensity aerobic activity weekly.[4] HRV measures the ability of the body to maintain proper functioning through the ANS by adjusting the influence of the PNS and SNS to meet the constant physiological adjustments that occur in the body. [9,10,12] HRV also has a relationship with cardiovascular health, which is an aspect of health that Americans need to continue improving.

Vinyasa yoga is a combination of asanas (physical postures), breathing, and being mindful by bringing the practitioners attention to their physical movements.[7] Since vinyasa yoga may be considered moderate-intensity exercise,[6] breathing has been shown to have effects on the ANS,[28] and paying attention/being mindful has evidence of stimulating the PNS,[28] it would be beneficial to see if vinyasa yoga has an effect on HRV and other ANS measurements beyond that which is seen with aerobic physical activity. The purpose of this study, therefore, is to examine the effect of a vinyasa yoga session on measures of autonomic nervous system function including HR, systolic BP, and HRV.

2.0 Review of the Literature

2.1 Autonomic Regulation of the Cardiovascular System

The autonomic nervous system (ANS) influences the cardiovascular system by many mechanisms including ANS interactions with the SA node of the heart, baroreceptor responses, and the phenomena known as respiratory sinus arrythmia (RSA). The two branches of the ANS adjust autonomic activity in the body by influencing heart rate (HR), blood pressure (BP), respiration rate, and digestion.[9] Physiologically, the roles of the sympathetic nervous system (SNS) and parasympathetic nervous system (PNS) have opposing effects. Signals are sent from the cardiovascular center of the brain, the medulla, to influence which component of the ANS is controlling the cardiovascular system at any time.[29] The SNS is commonly referred to as the "fight or flight" response because its activation leads to increased HR, BP, breathing rate, and decreased gastrointestinal peristalsis (wave-like muscle contractions that stimulate the digestive tract and facilitate digestion/absorbtion[30,11]).[9] When the SNS is activated, signals are sent through spinal cord nerves innervating the SA node, AV node, and myocardium, and there is up to a 5 second delay before a response occurs. Action potentials occur in these neurons causing norepinephrine and epinephrine to release and bind to beta-adrenergic receptors increasing depolarization of the SA/AV nodes. The stimulation from the SNS increases HR, heart contractility, and constricts blood vessel diameter.[29]

The PNS exerts it's effects more rapidly than the SNS, and it is the major influence of HR at rest.[29] It is known to increase "rest and digest" functions by decreasing HR, BP, breathing rate, and increasing gastrointestinal peristalsis.[9] The primary PNS pathway runs from the brainstem via

the vagus nerve (10th cranial nerve) through pathways that reach and influence the heart and lungs, and other organs.[11] The control that the vagus nerve has over the heart is referred to as the vagal tone.[12] Vagal tone contributes to our resting HR and BP as it is how active the vagal nerve is at rest. Signals are sent from the cardiovascular center of the brain through the vagus nerve innervating the SA node, AV node, and atria's cardiac muscle of the heart. When the vagus nerve is triggered, the post-ganglionic neuron releases acetylcholine that binds to muscarinic receptors to decrease the rate of depolarization of the SA and AV node to lower HR.[29] A lower resting HR and higher vagal tone has been linked to a lower risk of mortality. Similar to other components of our health, vagal tone has been found to decline with aging and improve with regular dynamic exercise.[11] Considering that vagal tone (the PNS activity) predominantly contributes to resting HR, BP, and HRV, we can assume that incorporating any form of exercise into a daily routine would have a positive influence on these parameters and thus our cardiovascular health.

HRV changes occur due to adjustments in BP and HR influenced by baroreceptors. Baroreceptors are located in the heart and aortic arch, and they regulate BP when the body notices that it is no longer in a healthy range. Signals are then sent to the medulla where a decision is made to alter SNS and PNS stimulation to the heart. The adjustments made change HR, vasoconstriction, and contractility to regulate BP.[29] The final component that is influenced by the ANS and respiratory drive to generate cardiovascular changes is seen as RSA. It is an index of vagal control of the heart and displays HR changes by shortening and lengthening beat-to-beat intervals in responses to the respiratory cycle, inhaling and exhaling, respectively. During an inhale, vagal influence is inhibited causing an increase in HR. Exhaling, restores vagal influence making the HR slow down.[31,32] Overall, it seems that changes in HR, BP, and HRV can be manipulated through multiple mechanisms.

2.1.1 Autonomic Nervous System and Exercise

Observing the functioning of the ANS may be a powerful tool in understanding the risk of CVD.[11] Specifically, HRV has been shown to determine cardio-autonomic dysfunction and predict all-cause mortality.[29] A review conducted by Freeman et al. acknowledged that traditional risk factors for CVD like age, lipid profile, and family history play a role in the development of CVD, but the interaction between the ANS and cardiovascular system may be more important when it comes to determining CVD mortality risk. This review found growing evidence that the measurement of HRV can be a prognostic tool when measured at rest or during exercise.[11]

Exercise is known to enhance the ANS by improving vagal tone.[33,34] The vagus nerve, the nerve that controls cardiac vagal tone, is the main factor of the PNS that reduces HR and BP; therefore, increasing HRV to improve cardiovascular health. The mechanisms by which exercise improves vagal tone are speculated to be by suppressing angiotensin II expression and increasing nitric oxide availability, both of which are considered to be cardiovascular regulators. Angiotensin II inhibits cardiac vagal activity by constricting blood vessels and inhibiting acetylcholine release at the presynaptic terminals of the vagus nerve.[34,35] These mechanisms increase BP and HR which inherently decreases HRV.[34] Nitric oxide is speculated to have opposite effects on vagal activity by enhancing it. Physical activity improves endothelial function and increases nitric oxide availability generating increased vagal output.[35] The consequence of increased vagal output through increased nitric oxide availability is vasodilation of the blood vessels and increased acetylcholine release from the vagus nerve.[36] The mechanisms that are mentioned here are the most current proposed mechanisms of how exercise training effects the ANS, but further research on these cardiovascular regulators is needed.

A few studies have been done to examine the role of various types of exercise on ANS function. First, a study conducted by Masroor et al. in hypertensive women found combined exercise training (resistance and aerobic exercise) to be an effective means to manage hypertension due to exercise's ability to improve cardiac autonomic control of the body. Specifically, the authors suggested that combined exercise training improved HRV, resting BP, and autonomic control of the body by increasing vagal tone, decreasing intrinsic HR, reducing vasomotor tone due to increased nitric oxide bioavailability, and speculation of decreased angiotensin 2 levels.[37] One study conducted by Weippert et al. found differences when two different types of exercises (cycling and static leg press) were performed in a reclined position at similar HR. BP ($p<0.001$) and HRV (SDNN: $p= 0.003$, RMSSD: $p=0.021$) differed significantly between reclined cycling and reclined static leg press. These results allowed the authors of this study to conclude that autonomic control processes differ between types of exercises, even when performed at similar workloads.[38]

Pilates is another form of exercise that has been studied and may be similar to vinyasa yoga because dynamic movements are performed while generating mental vitality. One study by Cavina et al. found a 12-week Pilates training program to significantly improve global variability of the ANS i.e., improving all rhythmic components responsible for variability.[39] Since there was an improvement in the ANS following a Pilates intervention, it is possible that vinyasa yoga could elicit similar results.

Different modes of exercise have been found to positively affect the ANS. The findings above demonstrate that exercise can improve autonomic control with exercise interventions improving HRV. Different types of exercise have been shown to alter the ANS functioning on the cardiovascular system, so it is important to have an understanding of ANS effects during all types of exercise to recognize if some exercise modes affect the ANS differently than others.

2.1.2 Acute Impacts of Exercise on Cardiac Autonomic Functioning

As highlighted in the previous section, there are benefits to cardiac autonomic functioning from long-term exercise interventions, but exercise impacts many physiological parameters during and following single acute bouts of exercise including BP, HR, and HRV. A review by MacDonald discussed that there is a hypotensive response in systolic BP in the minutes and hours following an acute exercise bout. MacDonald claimed that this phenomenon has been examined in many studies, with the reduction of BP occurring as early as 10-minutes post exercise and up to 170 minutes following an exercise bout.[40] Similar conclusions were drawn by Cardoso et al. who reviewed the literature and concluded that a single bout of aerobic exercise reduces ambulatory blood pressure for hours following the exercise bout, but the magnitude of a hypotensive response differs between individuals and exercise duration/type.[41] Romero et al. reviewed the cardiovascular system post exercise and determined that both aerobic and resistance exercise generates postexercise hypotension for several hours following an exercise bout. Similar to other studies, this review also concluded that exercise type, duration, and intensity play a role in post exercise hypotensive responses.[42] There are many proposed mechanisms that may play a role in post exercise hypotension, but it has been mainly found that this phenomenon is due to decreased vascular resistance (from persistent vasodilation) mediated by the ANS, baroreceptor responses, and increased bioavailability of vasodilators.[40, 42] Overall, post exercise hypotensive BP responses can occur within minutes of completing an exercise bout and these effects can continue for hours due to the decrease of vascular resistance.

Improvements in cardiovascular functioning (HR and BP) are seen with exercise.[43] HR is another physiological parameter that increases during exercise and decreases following exercise. The two branches of the ANS impact HR. There is an increase in SNS activity during an exercise

session that generates an increase in HR to maintain the changing physiological demands of the body. HR changes that occur immediately following an exercise bout are predominantly due to the immediate reactivation of the PNS; however, the continuous lowering of HR for the hours following exercise is generated by changes in both branches of the ANS. Following an exercise bout, the increase in SNS activity withdraws while PNS activity increases. These actions occurring simultaneously lower HR[44,42] It is suggested that HR decreases following an exercise bout, but the change in HR and the time it takes to return to or surpass baseline values varies depending on exercise duration and intensity.[8]

When it comes to HRV and bouts of exercise, HRV responses are similar to HR except that HRV has a linear decrease during exercise until higher exercise intensities where it plateaus at a lower value. The change in HRV has been found to differ between exercise modes, duration, and intensity. Micheal et al. reviewed HRV and exercise and found that HRV will return to baseline or potentially improve following exercise. [8] Seiler et al. studied HRV following bouts of running and discovered that HRV values returned to baseline within 5 minutes following lower intensity exercise and higher intensities took a minimum of 30 minutes to return to baseline values.[45]

Another study that included acute bouts of two different modes of exercise had different conclusions regarding HRV changes following exercise. A study by Esco et al., had subjects complete two different exercise sessions (treadmill and cycle) for 30-minutes at 65% of their VO2max. HRV measurements were recorded prior to the sessions and at two time periods post-exercise (between 8-13 and 23-28-minutes post exercise). These two post exercise time periods were chosen because the authors found they sufficiently reflected HRV recovery. A statistically significant decrease (i.e., the SNS was still active following the exercise bout) was found in the HF HRV measurement ($p<0.05$) following both post-cycling HRV recordings, and only during the

HRV recording taken 8-13 minutes post-treadmill session.[44] Based on these findings, a longer period may be necessary before HRV measurements would return to baseline.

A study conducted by Gambassi et al., included a longer period between the cessation of exercise and HRV measurements. Gambassi et al., observed HRV responses one hour and 24 hours post exercise compared to baseline. Following a 25-minute bout of moderate-intensity cycling, there were significant changes in cardiac autonomic control. The time domain measurement, root mean square of successive differences (RMSSD), had a significant positive change one-hour post exercise bout ($p=0.017$) and 24 hours post (0.007). The frequency domain HF measurement was significantly different only one-hour post session ($p=0.048$) compared to baseline measurements. Most of the HRV measurements significantly improved following the bout of moderate intensity exercise in this study, but it is important to address that this study had many limitations like a small sample ($n=8$) and no control group comparison. Overall, the authors concluded that their study demonstrated that a bout of moderate-intensity exercise is associated with improved autonomic control[46]

A study by Gladwell et al., also found a significant decrease (suggesting SNS dominance) in HRV measurements immediately following exercise, but Gladwell et al., also found HRV values returned to baseline or surpassed baseline values by 65-minutes post exercise. Subjects cycled in a supine position for 20 minutes at different intensities (1. Moderate 2. Hard 3. Vigorous), and HRV measurements were taken five times up to 65 minutes post exercise sessions. Time domain measurements were still significantly reduced ($p<0.001$) compared to baseline measures following the cycling bouts at all three intensities leading the authors to conclude that HRV values were depressed at 5-10 minutes postexercise and remained depressed until 15-20 minutes following an acute bout of exercise (timing depended on exercise intensity).This study contributes to the literature by suggesting that significant autonomic improvements do not occur until at least 15

minutes following a bout of exercise, and HRV measurements return to baseline (or surpass baseline values) between 30-65 minutes post exercise. The differences in HRV returning to baseline values or improving was dependent on exercise intensity. [47]

HRV changes following exercise occur with a similar mechanism to HR changes after exercise. HRV increases following exercise due to immediate PNS reactivation, but SNS activity does not dramatically decrease immediately following exercise due to the slow decrease of SNS activity during recovery. Immediate PNS reactivation and SNS withdrawal generate HRV increases immediately following a single bout of exercise.[44] Based on the findings of the studies discussed above, we can infer that systolic BP likely decreases below baseline measurements within 10-minutes following an exercise bout[40,48] and HR decreases quickly following a bout of exercise.[42] The findings related to HRV improvements from an exercise bout are mixed. Overall, the studies that have been reviewed have come to at least one similar conclusion. They have found that HRV measures at least one-hour post exercise may see increases or improvements in HRV measurements compared to baseline measurements.

2.2 Yoga

The word yoga comes from the Sanskrit language, and it means "to yoke, unite, or bring together." Yoga originated in India with the first recorded information dating back to the second century BCE. The practice of yoga was first introduced to Americans in 1893, and the more modern styles of yoga that are popular in the United States currently focus on improving health.[5,49] Now, millions of Americans are practicing yoga, with 36.7 million Americans practicing in 2016 following an increase of 15.6 million people between the years of 2012-2016.[5]

Yoga is a practice that promotes physical and mental well-being through physical postures (asanas), mindfulness/meditation (dyna), and breathing techniques (pranayama).[19] There are a variety of different styles of yoga that each provide different benefits. A few examples of the different styles of yoga include Hatha, vinyasa, power, Ashtanga, Bikram, Iyengar, yin, and restorative yoga.[50] There are many benefits to yoga including improving mental health,[19] sleep, [19] healthy habits,[19, 20, 21] strength, balance, flexibility, and heart health.[24]

The 2016 Yoga in America Study was conducted to determine how Americans view yoga. The study found that many people believe that they should be doing yoga with more, with 75% of Americans acknowledging that "yoga is good for you.". It was also found that the main reason people are practicing yoga is because of how it impacts their health and reduces stress. Of the yoga practitioners surveyed in 2016, 65% of them strongly agreed that one positive impact of yoga was that it was a stress-reliever. [5,7] Of the individuals that did not practice yoga, 67% of people at least somewhat agreed that yoga is a stress reliever. This informs us that many individuals utilize yoga as a way to decrease their stress levels.[5] Everyday stress that individuals endure has been shown to contribute to CVD.[51]

2.2.1 Autonomic Nervous System and Yoga

There have been three primary mechanisms proposed as to how yoga may influence ANS functioning and thus HRV, are reviewed here, which are increased vagal tone, controlled breathing, and mindfulness. There have been mixed results when it comes to the relationship between the ANS and yoga. As mentioned in Chapter 1 of this document, Bikram and Hatha yoga interventions did not demonstrate a relationship between HRV and yoga. Both of these studies reported that participant adherence needed to be improved in future studies to elicit stronger results

on yoga and HRV.[26,27] In contrast, a pilot study that included healthy young adults found a general improvement in HRV following a yoga intervention compared to regular school sports. Both interventions occurred in 90-minute sessions once a week for ten weeks. The yoga sessions included the basic components of a yoga class such as physical postures, breathing exercises, and relaxation techniques. The sports sessions followed standard school curriculums with an emphasis on basketball, volleyball, and badminton. HRV improvements in the yoga group were statistically significant for SDNN-standard deviation of normal-to-normal R-R intervals ($p=0.037$) and RMSSD ($p=0.024$). The improved HRV in this study was speculated to be due to more parasympathetic dominance from the yoga sessions compared to school sports. The specific style of yoga for this study was not specified by the authors, but the session included a warm-up, a more intensive physical practice, floor exercises, and silent meditation.[52]

A comprehensive review was conducted by Tyagi A, et al. to determine the relationship between yoga and HRV. The overall findings of this review suggested mixed results, but the suggested mechanism for increased ANS functioning or increased HRV from yoga is an increase in vagal tone/dominance.[53] Increased vagal tone/dominance is when signals from the cardiovascular center of the brain are sent to the SA node, AV node, and cardiac muscle of the heart causing an increased release of Ach/muscarinic binding that decreases depolarization producing a lower HR.[29] The authors of this review concluded that most of the studies conducted were poor quality due to inadequate reporting of study design, study population, specific yoga interventions, measurements, statistical analyses, and unstandardized conditions. They also concluded that very few studies included details of respiratory rate, which makes it difficult to conclude if HRV/ANS changes were due to the ANS or to cardiac control. Based on the findings of this review, the authors suggested that more rigorous, detailed studies are required to determine the association between the ANS and yoga.[53] A different review that included 14 studies concluded

that there is currently no convincing evidence that yoga modifies HRV, but any autonomic shift that was found is likely due to vagal dominance following a yoga intervention. Similar to the comprehensive review by Tyagi A et al., these authors concluded that future studies should overcome the weak methods of the available scientific literature.[54] Overall, few good quality studies have investigated ANS responses to yoga interventions, so more rigorous studies need to be conducted to elicit statistically significant results.

2.2.2 Autonomic Nervous System and Breathing

Breathing is one of the three components of vinyasa yoga.[19] A study was conducted by Sengottuvel Senthilnathan et al. to observe cardiac autonomic control during breathing. This study included 67 participants that were recruited for four different groups; a yogic group, normal breathing group, paced breathing group, and focused attention group.[28] The normal breathing group was considered the control group and thus the comparison group. The authors concluded that participants in a controlled low-frequency breathing group (less than 12 breathing cycles per minute) and the yogic group were similar, and these groups displayed significant differences in HRV parameters (higher variability between R-R intervals) compared to the normal breathing group likely due to RSA. The authors claimed that these results are consistent with many of other studies, so controlled breathing is a potential tool for long-term physiological benefits.[28]

Suggested benefits found from breathing are due to the PNS. Increased vagal activity occurs during breathing because vagal activity is suppressed during inhales and enabled during exhales and slow respiration cycles. When the vagus nerve is stimulated, it innervates the SA node of the heart and produces a decrease in HR. Clinicians and researchers have developed vagal nerve stimulation techniques to promote increased vagal activity, and breathing exercises have been

found as a form of vagal nerve stimulation to slow the HR. A slower HR influences improved autonomic functioning.[32]

2.2.3 Autonomic Nervous System and Mindfulness

Mindfulness has been described as tuning into and being fully aware of each and every moment.[55] It is one of the three components of vinyasa yoga that is typically associated with meditation.[19] A study by Chang et al. observed the effects of the ANS on the cardiovascular system with measurements including HR, BP, and HRV during Heart Chan meditation. The meditation sessions included breathing and concentration. This study included two different meditation interventions; Group 1 had no previous mediation experience and completed face-to-face meditation classes, while group 2 had meditation experience and completed video meditation classes. In total, there were 72 participants enrolled between the two groups of this study. The authors found a significant improvement in multiple cardiovascular measurements for both groups. HR changes following mediation were statistically significant, especially for group 2 where the p-values comparing baseline HRs to post HRs were statistically significant ($p<0.001$). Following the first mediation session in group 2 and after 1-month of meditation for both groups, there were significant improvements in HRV (group 1 after 1-month: $p=0.014$, group 2 after 1-month, $p=0.013$, and group 2 following the first session $p=0.015$). For this study, HRV age was defined as the age that the recorded HRV corresponds to with normative data. HRV age also had statistical significance in both groups (group 1 following the first session: $p=0.039$, group 2 following the first session $p=0.009$, and group 2 after 1-month $p=0.019$). Overall, this study concluded that short-term meditation classes were effective at improving ANS activity.[56]

Sengottuvel Senthilnathan et al. found that a focused attention group that performed cognitive tasks without any breathing instruction had similar parasympathetic dominance to the paced breathing and yogic groups of a study. This finding led the authors to conclude that focused attention is a yogic technique that can have short and long-term physiological benefits and train individuals to breathe at low pacing rates without intentionally focusing on breathing. Considering that focused attention (i.e., mindfulness) has been found to lead to slower breathing rates and that slow paced breathing stimulates higher variability between R-R intervals in HRV measurements, mindfulness likely improves autonomic functioning in a similar mechanism to breathing.[28]

2.3 Summary

Exercise, yoga, breathing, and mindfulness have all been found to improve autonomic regulation of the cardiovascular system. Many different exercise modes have been studied and are known to improve physiological components like BP, HR, and HRV. Some studies have investigated yogic methods on ANS functioning, but the available research on yogic methods and the ANS is limited to poor quality studies. More research is necessary to understand autonomic regulation of the cardiovascular system from a vinyasa yoga intervention that includes the three main components of a yoga practice (asanas, breathing, and mindfulness/meditation).

3.0 Methods

This study utilized a randomized crossover design to examine the effects of an acute vinyasa yoga condition compared to a control on autonomic nervous system (ANS) responses of the cardiovascular system. ANS responses were assessed through measures of systolic blood pressure (BP), heart rate (HR), and heart rate variability (HRV). Each of these variables were measured three times during the experimental and the control sessions; 1) at rest prior to the vinyasa yoga and control conditions, 2) 5 minutes after each condition, and 3) 65 minutes after each condition. Systolic BP, HR, and HRV were the primary variables evaluated for this study.

3.1 Subjects

A convenience sample of 18 unpaid volunteers who were healthy adults and had experience with vinyasa yoga were recruited for this study. Participants were required to have experience with vinyasa yoga to ensure that they could properly perform the yoga poses. Participant inclusion and exclusion criteria are included in the table below.

Table 1 Particpant Inclusion/Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
• Age: 18-55 years • Prior experience participating in vinyasa yoga (comfortable with pose names and performing them)	• Physical limitation that limits ability to perform vinyasa yoga (i.e., musculoskeletal injuries) • Presence of medical condition that requires medical clearance (i.e., cancer, heart disease, Type 1 or 2 Diabetes Mellitus) • Presence of any cardiovascular condition or previous cardiac event (i.e., CVD, myocardial infarction, peripheral artery disease) • Taking any medications that affect heart rate or blood pressure (i.e., anti-depressants, beta-blockers, calcium channel blockers, digitalis, and thyroid medications) • Pregnant women (determined through self-report during screening)

3.2 Recruitment and Screening Procedures

Participants were recruited through 1) fliers that were posted locally and 2) fliers given to students enrolled in classes in the Department of Health and Human Development at the University of Pittsburgh. Interested individuals contacted the investigator with the phone number or email provided on the recruitment flyers. Those who showed interest in the study were contacted by phone, given an overview of the study, asked to provide verbal consent to complete screening questions to determine initial eligibility, and scheduled a virtual (over Zoom) or in-person informed consent signing session. The script for the screening calls can be found in Appendix A. If a person appeared to be initially eligible, then they scheduled a consent signing session.

During the consent session, the participants were informed about the study, signed the consent (if they were still interested), were asked to confirm or elaborate on their answers to the screening questions that they already answered from Appendix A, and were asked to confirm that

they were able to perform a few common yoga poses (child's pose, crescent lunge, warrior 1, triangle pose, bridge pose, half pigeon, and legs in the air) ensuring that they were capable of performing some of the yoga poses that were in the vinyasa yoga sequence used for the intervention. Participants that had responses to the screening questions that would potentially exclude them from the study, were informed that their screening responses would be reviewed and that they would receive an email either confirming or denying eligibility of the study by the end of the next business day. At the end of the consent signing, the participants scheduled both of their in-person trials for the same time one week apart.

3.3 Assessment Procedures

Baseline measures were conducted only on the first visit in order to collect basic demographics and sample characteristics. These included age, gender, height, weight, and BMI:

- Age: Age was determined through participant self-report.
- Gender: Gender was determined through participant self-report.
- Height: Height was measured using a wall-mounted stadiometer and measured to the nearest 0.1 cm. A minimum of two measurements were taken. If the measurements differed by more than 0.5 cm, then a third height was taken. Following the third measurement, the criterion was achieved or the mean of all three measurements was calculated and used for data analysis.
- Weight: Weight was measured using a digital scale and measured to the nearest 0.1 kg. A minimum of two measurements were taken. If the measurements differed by more than 0.1 kg, then a third weight was taken. Following the third measurement,

the criterion was achieved or the mean of all three measurements was calculated and used for data analysis.

- BMI: BMI was calculated from the participant's measures of height and weight and computed as kg/m^2.

Additional assessments were performed immediately prior to each experimental condition, 5 minutes after, and 65 minutes after the conditions. Experimental conditions were conducted exactly one week apart to minimize time-of-day and day-of-the-week variations and standardize the visits. These measures include BP, HR, and HRV.

- Blood pressure: Systolic BP was measured using an Dinamap digital BP monitor on the left arm. The size of the BP cuff was determined by finding the midpoint of the humerus and measuring the circumference of the humerus's midpoint. The midpoint was found by measuring the distance between the acromion process of the scapula and the medial epicondyle of the humerus. The halfway point between those bony landmarks was where the circumference was measured. The circumference was utilized to apply an appropriately sized BP cuff to the participant. BP was taken before, 5 minutes after, and 65 minutes after the vinyasa yoga and control conditions. All BP measurements were taken following a 5-minute rest in a chair, in an upright seated position with back and arms supported, and with the participant's feet planted directly on the floor. At each timepoint, two BP measurements were taken one minute apart and the average from the two measurements was used for data analysis.
- Heart rate: HR was measured in beats per minute (bpm) from the Polar heart rate monitor recording of the r-wave to r-wave (R-R) intervals. The mean HR from the

first 5 minutes of the HRV recording was used for data analysis. HR was recorded by the principal investigator from the Polar heart rate monitor in the last 10 seconds of every minute during the different conditions on the data sheets in Appendix B (vinyasa yoga session) and Appendix D (control session).

- Heart rate variability: Short-term HRV (measurements that are less than 30-minutes) were collected with a Polar heart rate monitor and analyzed using the Kubios HRV software. The Polar heart rate monitor is a chest band that was applied to the participant's skin below the sternum. The time domain measures of mean HR, standard deviation of normal-to normal R-R intervals (SDNN), and root mean square of successive differences (RMSSD) were calculated from the R-R intervals, and the only frequency domain variable that was collected using Kubios was the high frequency (HF) HRV parameter. All of the time and frequency domains that were calculated are defined in Table 2 below.[57] SDNN and RMSSD were chosen as time domain metrics in this study because SDNN has been found to represent overall variability and RMSSD has been found to represent cardiac-vagal fluctuation influenced by respiration.[58] HF was the only frequency domain chosen to be recorded because it is the only frequency domain that has studies demonstrating a strong association with parasympathetic activity, while other frequency domain measures have evidence suggesting that a better understanding is necessary to draw conclusions from them.[59] HRV was measured before, 5 minutes after, and 65 minutes after the vinyasa yoga and control conditions. Each HRV measurement was taken for 6 minutes to ensure that there was at least 5 minutes of usable data. [53,58] Subjects were instructed to breathe with their normal breathing

pattern during the HRV recording, and the Kubios software calculated breathing cycles per minute.

Table 2 Heart Rate Variability Measurements

Heart Rate Variability Measurements		
Time-Domain Measures		**Units**
Mean HR (mean heart rate)	Average heart rate across the HRV measurement	Bpm
SDNN (standard deviation of normal R-R intervals)	Overall variation between the R-R intervals	Time (ln)
RMSSD (root mean square of successive differences)	Measures short-term variability, parasympathetic activity	Time (ln)
Frequency-Domain Measures		
HF (high frequency)	Parasympathetic nervous system activity and respiratory sinus arrythmia component centered around respiratory frequency	Absolute value of power (log)

- Standardized Subjective Exercise Experience Scale (SEES): In addition to physiological measurements, one survey was administered (located in Appendix E) to assess the psychological responses to an exercise stimulus. The survey, referred to as the Standardized Subjective Exercise Experience Scale (SEES), was created and validated by McAuley and Courneya (1994) and uses self-report to measure positive/negative psychological factors with a 12-question survey in a three-factor structure. Two of the factors relate to positive/negative emotions associated with psychological distress (PD) and positive well-being (PWB), and the third factor represents fatigue (FAT). Participants rated their agreement with current feelings on a 7-point Likert scale ranging from (1) not at all to (7) very much so. Internal consistency coefficients for this scale include PWB= 0.86, PD= 0.85, and FAT=0.88. This survey was given to subjects following the 5-minute rest and prior to the assessments of BP, HR, and HRV that occur at baseline, 5 minutes after, and 65

minutes after both in-person conditions. The responses were scored by totaling the values of the survey responses related to the three factors PWB, PD, and FAT to be used for data analysis.[60]

3.4 Experimental Design

A randomized crossover design was utilized (see Figure 1) where the subjects acted as their own control. Subjects were randomized using the sealed envelope technique. Before recruitment began, 18 opaque envelopes were filled, sealed, and randomly numbered. Nine envelopes included experimental condition 1 (conditions ordered as yoga, then control), and nine included experimental condition 2 (conditions ordered as control, then yoga). The next sequential envelope was opened when a participant arrived for the first in-person assessment visit.

Under both conditions, the subjects completed the orientation first, and then they were randomized to an experimental condition. Both the vinyasa yoga and control conditions were 60 minutes in duration.

A. Experimental Condition 1:

Virtual Orientation → Vinyasa Yoga Session → Control Session

B. Experimental Condition 2:

Virtual Orientation → Control Session → Vinyasa Yoga Session

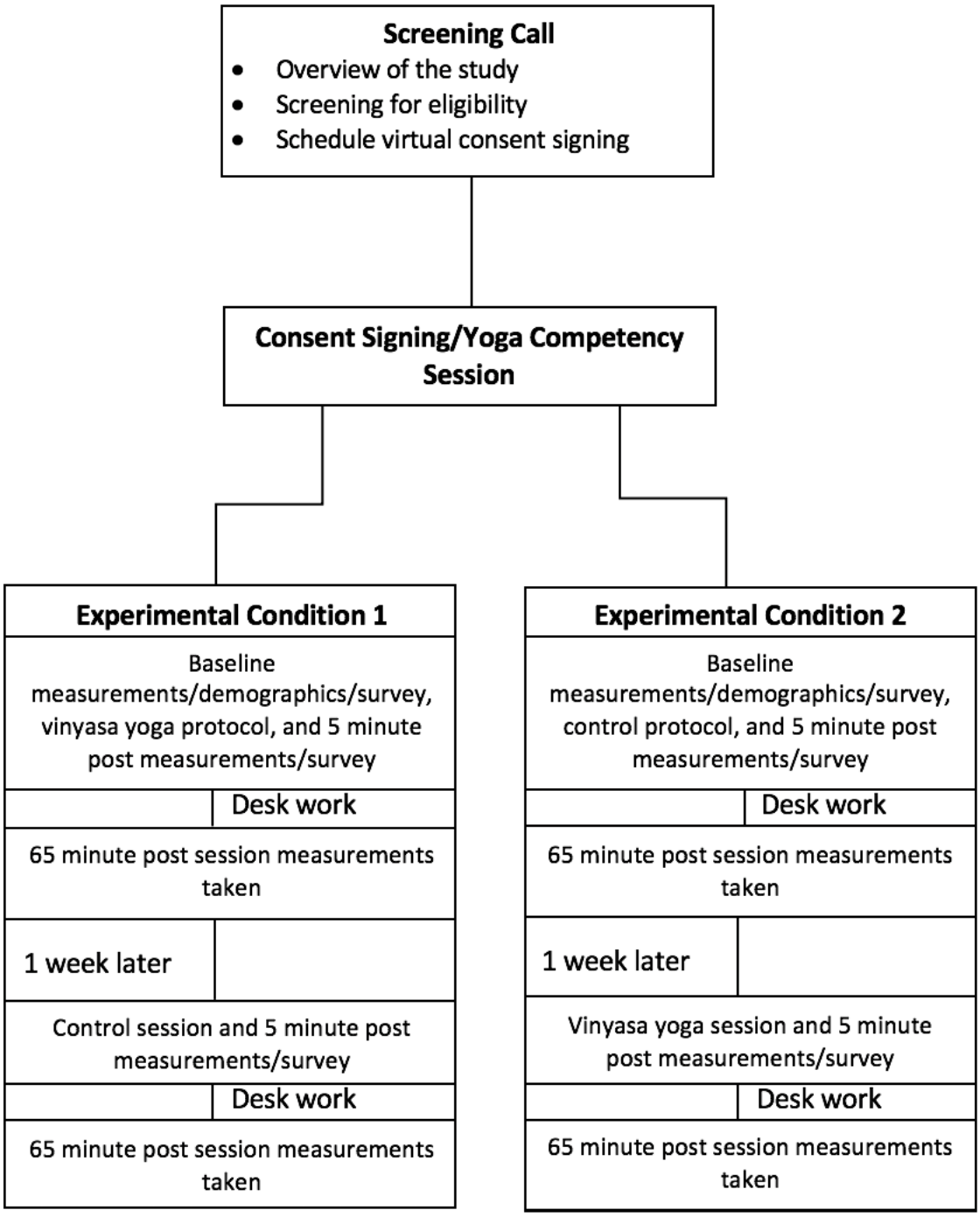

Figure 1 Experimental Flow Diagram

3.5 Experimental Conditions

Each visit was scheduled for the same time and day of the week, one week apart. HR, BP, and HRV measurements were taken following a 5-minute rest/survey completion prior to each condition, 5 minutes post condition, and 65 minutes post condition.

3.5.1 Vinyasa Yoga Session

The individuals were required to wear comfortable clothes that allowed for ease of movement during the yoga sessions. They were also asked to refrain from nicotine and caffeine for six hours prior to their scheduled visit, refrain from eating for 3 hours prior, and refrain from intense exercise and alcohol consumption for 24 hours before the visit. To standardize the sessions, a yoga mat and yoga block were provided for the subjects and subjects were required to perform yoga in bare feet. Before the vinyasa yoga condition, baseline measurements/demographics were taken with a Polar heart rate monitor and BP cuff that were applied to the subjects while instructions about the session were explained to them. Then, subjects were instructed to sit quietly for 5 minutes, in a chair, in an upright position, with their feet planted directly on the floor. Following this 5-minute rest, subjects' resting BP, HR, and a 6-minute HRV measurements will be taken. The BP cuff was removed following the resting measurements prior to the yoga session. Subjects completed the SEES survey following the 5-minute rest, but prior to the BP, HR, and HRV measurements. The Polar heart rate monitor remained on the subjects to record HR during the yoga condition, in the last 10 seconds of every minute, with the data sheet located in Appendix B. Following the baseline measurements but prior to completing the yoga condition, the subjects

were given the list of yoga poses that are included in Appendix C. After they reviewed the list of yoga poses, they were allowed to ask for pose demonstrations of any poses from the protocol.

During the yoga condition, the subjects followed a yoga video that was used as the protocol in the study conducted by Sherman et al.,[6] that included instructor cues of pose names and a person demonstrating the poses. More instructor cues were added to this video to provide additional, breathing, and specific mindfulness cues. The yoga sequence was 60-minutes and is detailed in Appendix C as a version of the *Journey into Power* sequence by Baron Baptiste.[61] The subjects were instructed to take any pose modifications that they would typically use in their own yoga practice. During the yoga condition, the investigator observed the subject's form and verbally corrected the subjects as necessary. The room temperature was also controlled during the vinyasa yoga sessions. The room's temperature was maintained between 68-72 degrees Fahrenheit.

The BP cuff was placed on the subject when they moved to the resting measurement chair immediately following the yoga condition, then BP, HR, and 6-minutes of HRV was measured at 5 minutes and 65 minutes post session. The SEES survey was administered to the subjects following the 5-minute rest periods but prior to the BP, HR, and HRV measurements. See Figure 2 for the vinyasa yoga session experimental design. The post yoga condition measurements were

all taken following a 5-minute rest in a chair, in an upright position, with participant's feet planted directly on the floor.

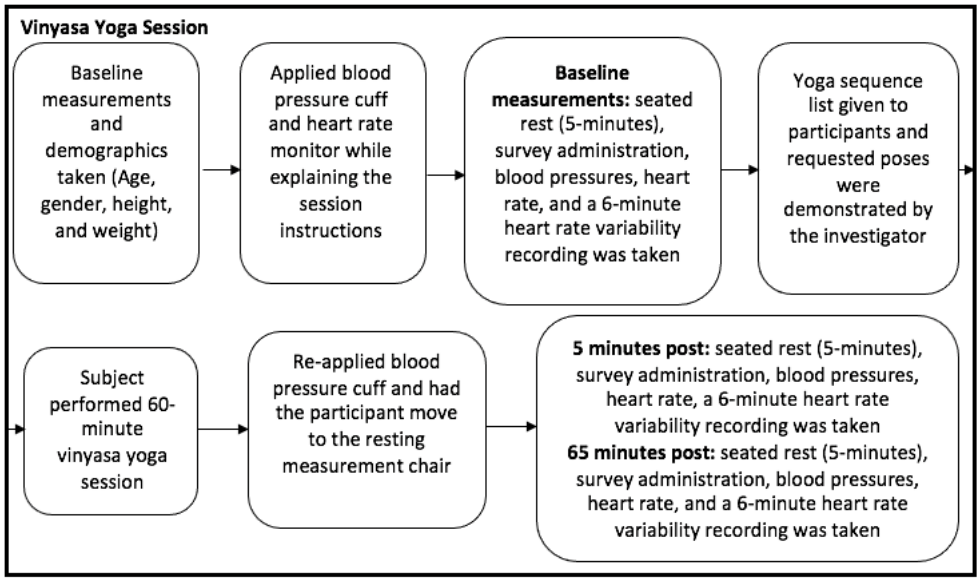

Figure 2 Vinyasa Yoga Session Experimental Design

3.5.2 Control Session

The subjects were required to wear comfortable clothes. They were also asked to refrain from nicotine and caffeine for six hours prior to their scheduled visit, refrain from eating for 3 hours prior, and refrain from intense exercise and alcohol consumption for 24 hours before the visit. Before the control condition, a Polar heart rate monitor and BP cuff was applied to the subjects and instructions about the session were explained to them. Then, subjects were instructed to sit quietly for 5 minutes, in a chair, in an upright position, with their feet planted directly on the floor. Following this 5-minute rest, subjects' resting BP, HR, and a 6-minute HRV measurement were taken. The BP cuff was removed following the resting measurements and prior to the documentary viewing. Subjects completed the SEES survey following the 5-minute rest period, but prior to the BP, HR, and HRV measurements. The Polar heart rate monitor remained on the

subjects to record HR during the documentary viewing, in the last 10 seconds of every minute, with the data sheet located in Appendix D.

During the control condition, subjects were seated in a supportive chair where they watched a nature documentary, *72 Cutest Animals*,[62] for 60-minutes. Similar to the vinyasa yoga session, the room temperature was monitored and maintained at a temperature between 68-72 degrees Fahrenheit.

The BP cuff was placed on the subject when they moved to the resting measurement chair immediately following the documentary viewing condition for the BP, HR, and 6 minutes of HRV that were measured 5 minutes post and 65 minutes post condition. See figure 3 for the documentary viewing experimental design. The SEES survey was given for the subjects to complete following the 5-minute rest periods, but prior to the BP, HR, and HRV measurements. The post measurements of BP, HR, and 6 minutes of HRV were taken following a 5-minute rest in a chair, in an upright position, with participant's feet planted directly on the floor.

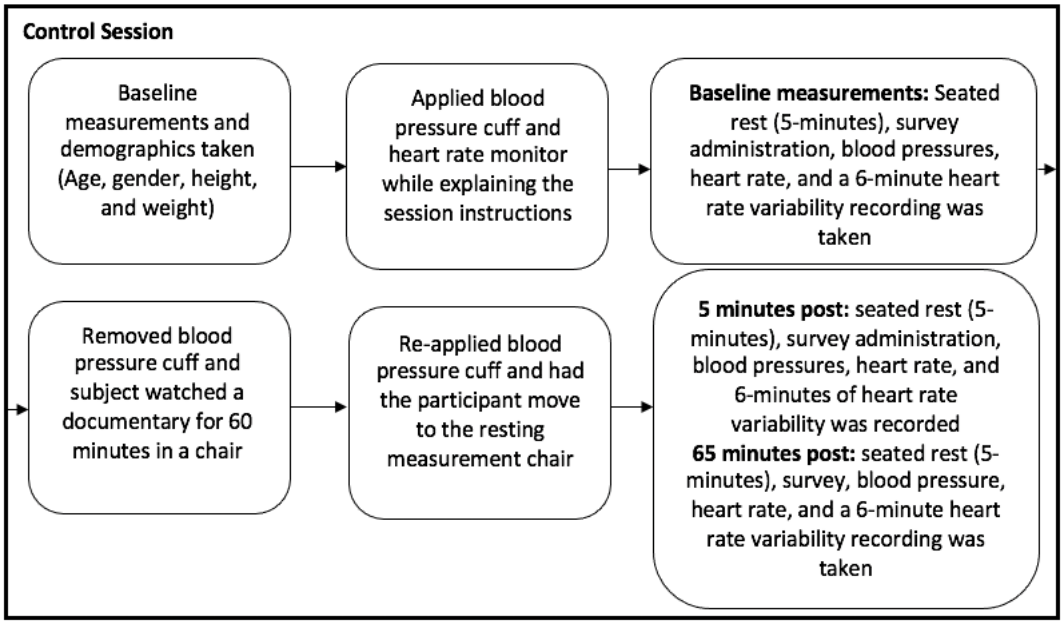

Figure 3 Control Session Experimental Design

3.6 Statistical Analysis

Statistical Analyses were performed using Stata SE version 17.0 with a statistical significance level of $p<0.05$. To examine Specific Aims 1, 2, and the first two exploratory hypotheses, paired t-tests were performed to find potential differences within-subject for each variable (SBP, mean HR, SDNN, RMSSD, HF, and scored survey data) at the different time points of measurement (time point 1- 5 minutes following the yoga and control conditions, time point 2- 65 minutes post-yoga and control conditions) compared to the baseline resting measurements. To examine Specific Aim 3, a linear mixed effects model was performed to compare each variable (BP, HR, mean HR, SDNN, RMSSD, and HF) and survey responses overall and at the different time points of measurement (time point 1- 5 minutes following the yoga and control conditions, time point 2- 65 minutes post-yoga and control conditions) between conditions. Before analyses, baseline values were adjusted for covariants.

3.7 Power Analysis

Cavina et al. suggested that a 12-week Pilates intervention promoted significant improvement in HRV, specifically, the time domain variable of SDNN and frequency domain variable of LF.[39] Stata SE version 17.0 was used to run a power analysis to determine an appropriate sample size. Cavina et al. found effect sizes of HRV measures to be moderate values.[39] Based on these previous findings, the power test for this study included an effect size was 0.5, with a power set at 0.80, and the type 1 error rate set at $p =0.05$. It was determined that 18 subjects (9 men and 9 women) would be required to participate in this study.

4.0 Results

The purpose of this study was to examine the effects of an acute bout of vinyasa yoga on the autonomic nervous systems (ANS) functioning within the cardiovascular system. A randomized crossover design was utilized to determine these effects and are presented in the following sections. All data was checked for normal distributions before analyses were performed and log transformations were conducted when appropriate.

4.1 Participants

A total of 22 individuals contacted the principal investigator by email or phone from flyers posted locally and given to undergraduate students enrolled in classes at The University of Pittsburgh. One subject never responded to the principal investigator to be screened/enrolled. Three of the interested individuals were screened and determined ineligible due to taking medications that are included in the exclusion criteria of this study (n=2) or not having availability to schedule (n=1). Eighteen (female: n=9, male: n=9) of these individuals completed the screening phone call, consent session, and both in-person sessions. Two subjects completed their initial in-person visit and needed to reschedule their second visit last minute, so they were rescheduled for a different weekday at the same time as their first visit. Complete data was used for analyses of 17 of the subjects. One subject's heart rate (HR) and heart rate variability (HRV) values were

excluded due to insufficient quality of the HRV recording, but their other measurements (blood pressure and survey data) were still included in statistical analyses (Figure 4).

Table 3 below displays participant characteristics. On average, participants were 28.7 years old with an average BMI of 27.4 kg/m^2. Three participants (17%) self-reported that they did not meet the current physical activity guidelines due to being physically active for less than 150 minutes a week. Fifteen participants self-reported meeting the current physical activity guidelines of at least 150 minutes of physical activity a week. Seven participants reported that they were currently practicing yoga at least one day a week when they participated in the study. Participants reported the type of physical activity that they regularly performed weekly, and these are displayed in Table 3 below. It is also worth noting that although not a specific aim of this study, Appendix

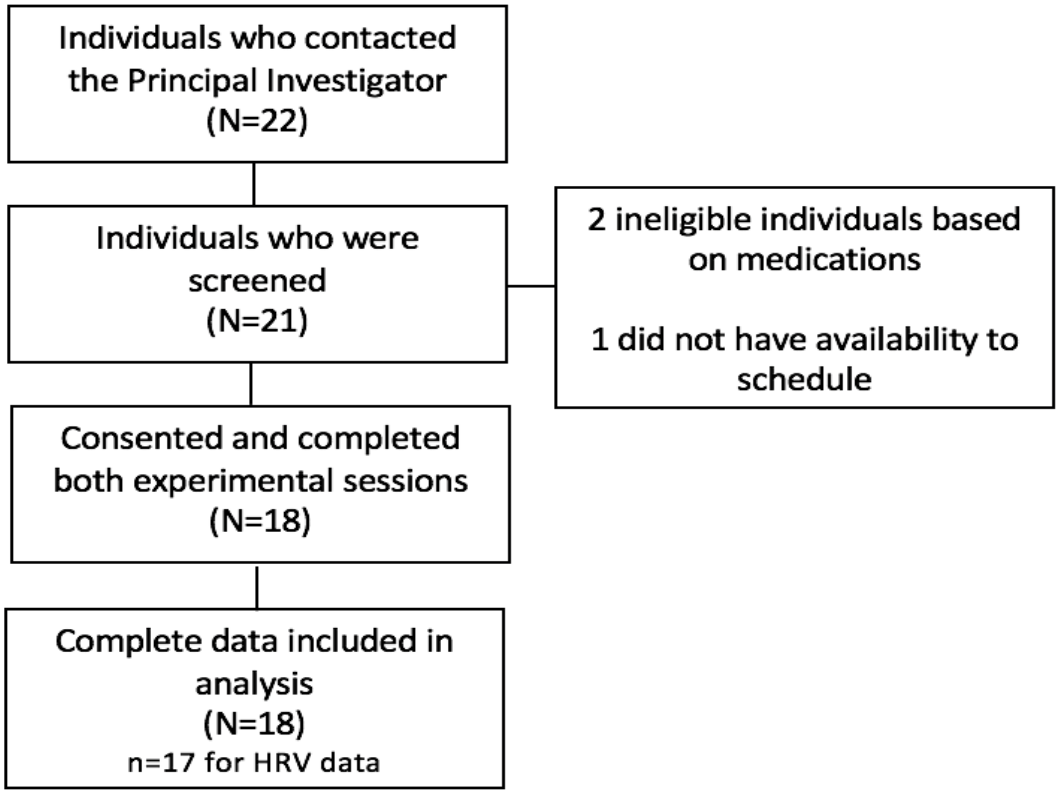

Figure 4 Participant Flow Chart

F includes yoga poses that subjects modified during the yoga condition and the modifications of those poses.

Table 3 Participant Characteristics

Characteristics (N=18)	Mean (SD) or n (%)
Age (years)	28.7 (9.4)
BMI (kg/m^2)	27.4 (5.6)
Gender	
Male	9 (50)
Female	9 (50)
Weekly Exercise Minutes	
0-149 (min/week)	3 (17)
>150 (min/week)	15 (83)
Number of Times Currently Practicing Yoga Weekly	
0 (days/week)	11 (61)
>1 (days/week)	7 (39)
Types of Physical Activity	
None	1 (6)
Biking/Cycling/Spinning	6 (33)
CrossFit	1 (6)
HIIT	1 (6)
Hiking	1 (6)
Jujutsu	1 (6)
Pilates	1 (6)
Rock Climbing	1 (6)
Running	6 (33)
Soccer	1 (6)
Swimming	1 (6)
Walking	16 (89)
Weight Training	10 (56)
Yoga	7 (39)

4.2 Data Analyses by Specific Aim

4.2.1 Specific Aim 1: Yoga Condition Physiological Outcomes

Paired t-tests were performed to analyze the first specific aim: to examine the effect of a vinyasa yoga session on heart rate (HR), systolic blood pressure (SBP), and heart rate variability (HRV) at 5 minutes and 65 minutes post yoga compared to baseline values. It was hypothesized that these physiological measurements would improve by 65 minutes post condition compared to the baseline measurements. Blood pressure, HR, and HRV results are summarized in Table 4 below.

SBP was not significantly different during the 5 (p=0.067) and 65 (p=0.749) minute post yoga measurements compared to baseline values. Although the decrease in SBP values were not significant, there was a 3.5 mmHg decrease in SBP values 5 minutes post yoga compared to baseline values and a 0.5 mmHg decrease in SBP at 65 minutes compared to baseline values. All

Table 4 Yoga Condtion Physiologcial Outcomes

Physiological Outcomes	Baseline		5 Minutes Post Yoga		65 Minutes Post Yoga		Baseline-5 Minutes Post Yoga		Baseline-65 Minutes Post Yoga	
Blood Pressure (n=18)	Mean	SD	Mean	SD	Mean	SD	Mean Difference	p-value	Mean Difference	p-value
SBP (mmHg)	110.3	8.99	106.8	12.5	109.8	10.7	-3.5	0.067	-0.5	0.749
DBP (mmHg)	67.03	9.52	63.86	9.75	67.66	9.75	**-3.2**	****0.011**	0.63	0.738
Heart Rate Variability (n=17)										
HR (bpm)	70.6	7.73	77.2	10.2	71.4	8.77	**6.60**	****0.023**	0.73	0.622
SDNN (ln)	3.66	0.43	3.53	0.37	3.71	0.08	-0.13	0.210	0.05	0.413
RMSSD (ln)	3.42	0.50	3.20	0.55	3.41	0.40	-0.22	0.070	-0.01	0.926
HF (log)	5.55	1.34	5.60	1.16	5.80	1.09	0.04	0.871	0.25	0.255

** Before a p-value indicates that the results were statistically significant

blood pressures were measured on left arms for consistency, but two subjects had to have their blood pressures taken on their right arms.

HR significantly increased 5 minutes post yoga compared to baseline (p=0.023). Sixty-five minutes post yoga, HR had almost returned to baseline with the mean difference between baseline and 65 minute post yoga measures being 0.73 bpm. No significant changes were found in HRV measurements 5 minutes and 65 minutes post condition compared to baseline values (SDNN: p=0.210, p= 0.413; RMSSD: p=0.070, p=0.926; HF p=0.871, p=0.255). HRV responses post yoga mostly decreased at both post condition measures, but HF values increased at 5 (+0.04) and 65 minutes (+0.25) post yoga and SDNN increased during the 65 minute (+0.05) post condition measurements. Kubios software accounted for respiration rates during HRV recordings. It was utilized to determine that respiration rates remained between 9-24 breathing cycles per minute (0.15-0.40 Hz) during HRV recordings.[58] All HRV data used for analyses included respiration rates between 9-21 breathing cycles per minute. Remaining within this breathing window allows us to determine that the high frequency (HF) HRV measurement is a valid measurement of parasympathetic activity. Overall, there was a decrease in blood pressure measurements following a 65-minute bout of vinyasa yoga, an increase in HR, and mixed HRV responses.

4.2.2 Specific Aim 2: Control Condition Physiological Outcomes

Paired t-tests were performed to examine the effect of a seated control (documentary viewing) on SBP, HR, and HRV 5 minutes and 65 minutes after a viewing 60 minutes of a documentary compared to baseline values. The physiological outcomes taken during the control session are included in Table 5 below. SBP changes were not significant at 5 (p=0.097) and 65 minutes (p=0.097) post control. HR significantly decreased at 5 (p=0.001) and 65 (p=0.002)

minutes post control compared to baseline values. All HRV values recorded significantly increased following the seated control condition (SDNN: p=0.018, p=0.001; RMSSD: p=0.001, p=0.001; HF: p=0.001, p=0.022). Overall, blood pressure increased, HR decreased, and HRV increased after viewing the documentary.

Table 5 Control Conditon Physiologicol Outcomes

Physiological Outcomes	Baseline		5 Minutes Post Documentary		65 Minutes Post Documentary		Baseline-5 Minutes Post Documentary		Baseline-65 Minutes Post Documentary	
Blood Pressure (n=18)	Mean	SD	Mean	SD	Mean	SD	Mean Difference	p-value	Mean Difference	p-value
SBP (mmHg)	108.0	5.72	112.8	12.6	110.6	8.69	4.8	0.063	2.6	0.097
DBP (mmHg)	65.9	9.77	68.2	9.37	67.9	6.89	2.3	0.123	2.0	0.120
Heart Rate Variability (n=17)										
HR (bpm)	71.3	9.14	66.7	6.64	66.9	7.66	**-4.6**	****0.001**	**-4.4**	****0.002**
SDNN (ln)	3.60	0.44	3.76	0.39	3.83	0.35	**0.16**	****0.018**	**0.22**	****0.001**
RMSSD (ln)	3.34	0.55	3.61	0.47	3.63	0.42	**0.26**	****0.001**	**0.28**	****0.001**
HF (log)	5.80	1.24	6.30	1.07	6.25	0.91	**0.48**	****0.001**	**0.45**	****0.022**

** Before a p-value indicates that the results were statistically significant

4.2.3 Specific Aim 3: Physiological Outcomes Comparison between Conditions

A linear mixed effects model was used to compare post condition physiological responses between the yoga and control experimental conditions. Specific aim 3 was to examine the differences in HR, SBP, and HRV 5 minutes and 65 minutes post yoga compared to a control. Comparison physiological outcomes between the yoga and control conditions are included in Table 6 below.

Figure 5 shows that SBP was significantly lower overall and 5 post yoga compared to the control (overall: p=0.000, 5 minutes: p=0.000). SBP was not significantly different between

interventions at 65 minutes following the yoga and control condition (p=0.136). HR was significantly higher overall (p=0.000), 5 minutes post (0.000), and 65 minutes (p=0.002) post yoga compared the control condition (Figure 6). HRV measurements were significantly lower overall (SDNN: p=0.000; RMSSD: p=0.000; HF: p=0.002), at 5 minutes post (SDNN: p=0.006; RMSSD: p=0.000; HF: p=0.008), and at 65 minutes post (SDNN: p=0.001; RMSSD: p=0.000; HF: p=0.209) conditions following the yoga compared to the control (Figures 7-9).

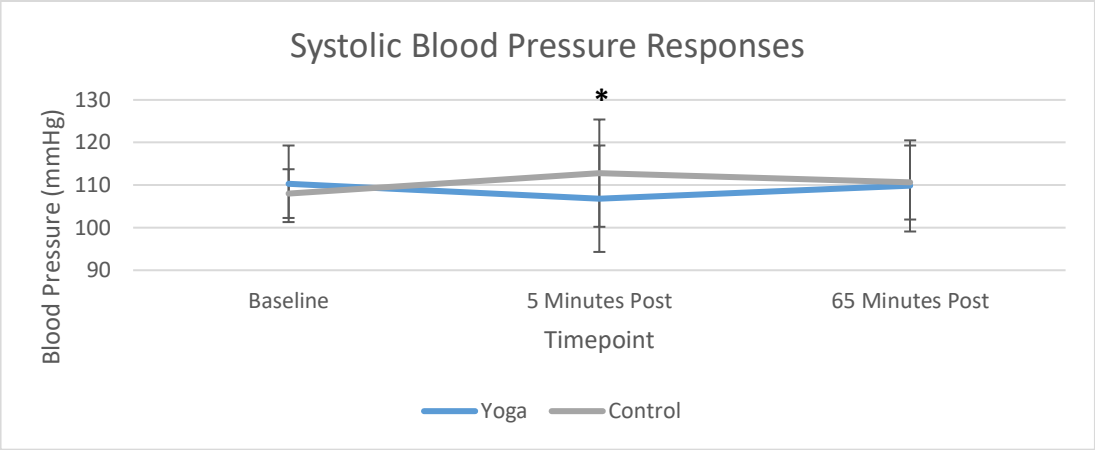

Figure 5 Systolic Blood Pressure Responses between Conditions

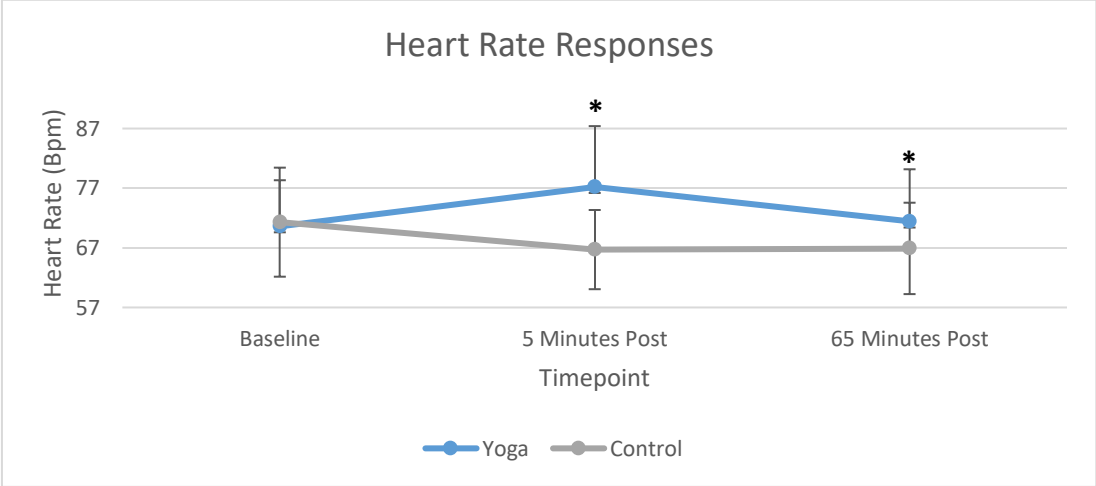

Figure 6 Heart Rate Responses between Conditions

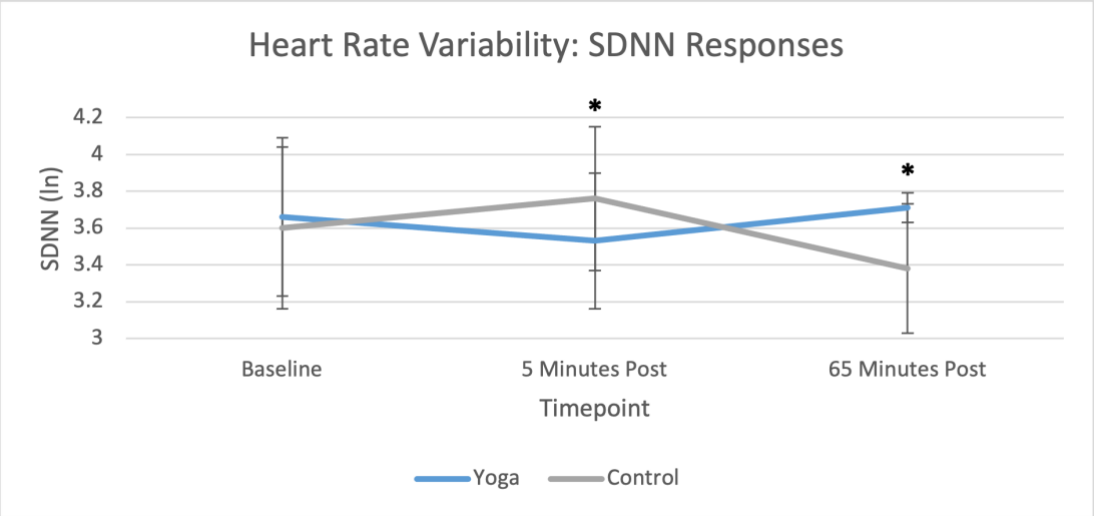

Figure 7 SDNN Responses between Conditions

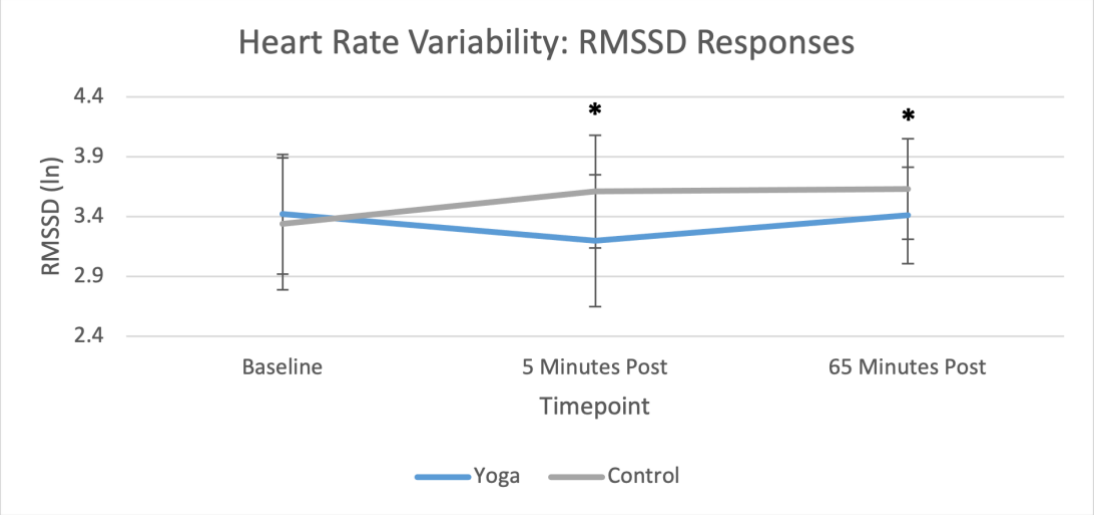

Figure 8 RMSSD Responses between Conditions

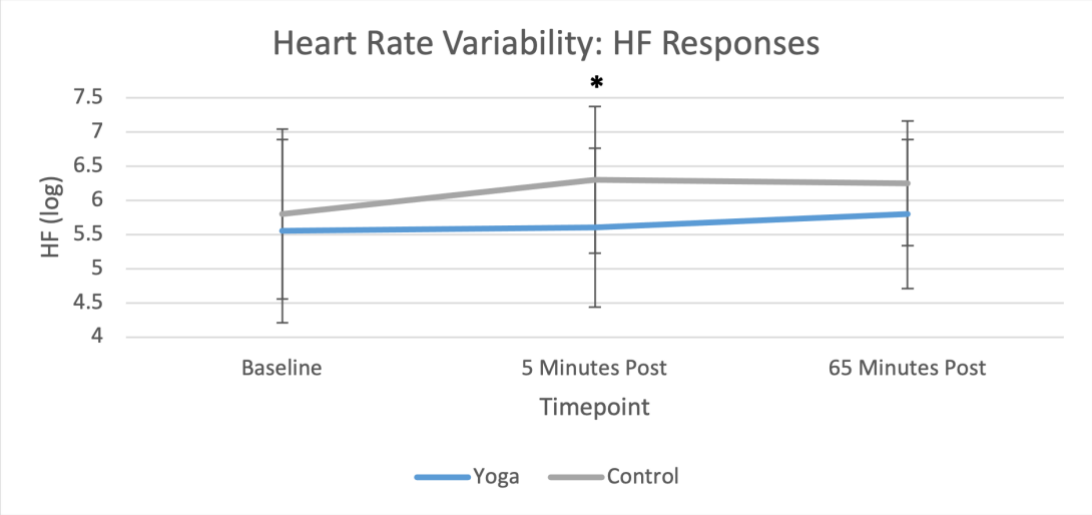

Figure 9 HF Responses between Conditions

Table 6 Physiological Outcomes Between the Yoga and Control Conditions

Physiological Outcomes Between Yoga and Control Conditions		
Factor	**Average Difference**	**P-value**
SBP (mmHg, n=18)		
Overall	-4.94	**0.000
5 Minutes Post	-8.14	**0.000
65 Minutes Post	-2.76	0.136
DBP (mmHg, n=18)		
Overall	-3.14	**0.005
5 Minutes Post	-5.62	**0.000
65 Minutes Post	-0.70	0.668
HR (bpm, n=17)		
Overall	7.67	**0.000
5 Minutes Post	10.49	**0.000
65 Minutes Post	4.70	**0.002
SDNN (ln, n=17)		
Overall	-0.19	**0.000
5 Minutes Post	-0.24	**0.006
65 Minutes Post	-0.14	**0.001
RMSSD (ln, n=17)		
Overall	-0.39	**0.000
5 Minutes Post	-0.49	**0.000
65 Minutes Post	-0.29	**0.000
HF (log, n=17)		
Overall	-0.41	**0.002
5 Minutes Post	-0.51	**0.008
65 Minutes Post	-0.26	0.209

** Before a p-value indicates that the results were statistically significant

4.2.4 Exploratory Aim: Survey Outcomes

Paired t-tests were performed to examine the positive and negative psychological responses 5 and 65 minutes post vinyasa yoga compared to baseline responses. The yoga condition paired t-test results can be found in Table 7. Each Factor (PWB, PD, and FAT) included the sum of four numerical survey responses, and the paired t-test responses for each individual response are also included in Table 7. Positive well-being (PWB) responses were significantly higher 5 minutes post yoga (p=0.011) and not significantly different 65 minutes post yoga (p=0.634). Psychological distress (PD) responses were not significantly different 5 minutes (p=0.205) or 65 minutes (p=0.230) post yoga compared to baseline measurements. Fatigue (FAT) responses were not

Table 7 Yoga Condition SEES Survey Outcomes

Standardized Subjective Exercise Scale Responses (Yoga, n=18)	Baseline		5 Minutes Post Yoga		65 Minutes Post Yoga		Baseline-5 Minutes Post Yoga		Baseline-65 Minutes Post Yoga	
	M	SD	Mean	SD	Mean	SD	Mean Difference	p-value	Mean Difference	p-value
PWB	3.04	0.20	3.09	0.19	3.03	0.25	**0.05**	****0.011**	-0.01	0.634
Strong	1.66	0.24	1.70	0.21	1.63	0.34	0.05	0.1174	-0.03	0.484
Great	1.71	0.20	1.77	0.15	1.63	0.34	0.07	0.036	-0.08	0.132
Positive	1.68	0.24	1.75	0.22	1.69	0.26	0.07	0.086	0.17	0.564
Terrific	1.50	0.49	1.52	0.50	1.51	0.50	0.02	0.630	0.01	0.835
PD	1.51	0.23	1.43	0.33	1.44	0.14	-0.08	0.205	-0.07	0.230
Crummy	0.12	0.27	0	0	0.04	0.16	-0.12	0.083	-0.08	0.331
Awful	0.08	0.22	0.19	0.11	0.39	0.46	0.12	0.331	-0.04	0.331
Miserable	0.12	0.36	0	0	0.10	0.29	-0.12	0.187	-0.02	0.892
Discouraged	0.12	0.27	0	0	0.04	0.16	-0.12	0.083	-0.08	0.163
FAT	2.14	0.49	2.04	0.46	1.94	0.56	-0.10	0.259	**-0.204**	****0.049**
Exhausted	0.65	0.53	0.60	0.56	0.65	0.53	-0.05	0.614	-0.23	0.067
Fatigued	0.70	0.64	0.67	0.49	0.60	0.63	-0.01	0.985	-0.07	0.504
Tired	0.89	0.54	0.79	0.48	0.69	0.57	-0.1	0.486	-0.22	0.156
Drained	0.60	0.63	0.47	0.53	0.60	0.59	-0.13	0.321	-0.18	0.192

PWB= Positive Well Being, PD= Psychological Distress, FAT= Fatigue
** Before a p-value indicates that the results were statistically significant

significantly lower 5 minutes (p=0.259) post yoga, but FAT responses were significantly different 65 minutes (p=0.049) post yoga compared to baseline values.

Paired t-tests were performed to examine the positive and negative psychological responses 5 and 65 minutes post a seated control compared to baseline responses (Table 8). PWB responses were not significantly different 5 (p=0.853) and 65 minutes (p=0.156) post control compared to baseline. PD responses were not significantly different 5 minutes post control (p=0.086); however, PD responses were significantly different 65 minutes post control (p=0.049) with a decrease of 0.04 (on a logarithmic scale). FAT responses had significant decreases 5 (p=0.014) and 65 minutes (p=0.010) post control condition.

Table 8 Control Session SEES Survey Responses

Standardized Subjective Exercise Scale Responses (Control, n=18)	Baseline		5 Minutes Post Documentary		65 Minutes Post Documentary		Baseline-5 Minutes Post Documentary		Baseline-65 Minutes Post Documentary	
	Mean	SD	Mean	SD	Mean	SD	Difference	p-value	Difference	p-value
PWB	3.05	0.22	3.04	0.23	3.01	0.25	-0.01	0.853	-0.04	0.156
Strong	1.66	0.25	1.6	0.33	1.58	0.34	-0.07	0.181	-0.07	0.142
Great	1.67	0.22	1.70	0.21	1.58	0.34	0.02	0.579	-0.09	0.111
Positive	1.73	0.20	1.74	0.19	1.65	0.21	0.01	0.753	-0.07	0.017
Terrific	1.60	0.32	1.56	0.34	1.56	0.35	-0.04	0.489	-0.04	0.449
PD	1.52	0.28	1.47	0.21	1.49	0.25	-0.06	0.086	**-0.04**	****0.049**
Crummy	0.18	0.35	0.08	0.22	0.14	0.33	-0.10	0.174	-0.04	0.331
Awful	0.14	0.33	0.08	0.22	0.08	0.22	-0.06	0.178	-0.06	0.178
Miserable	0.12	0.27	0.04	0.16	0	0	-0.8	0.163	-0.12	0.083
Discouraged	0.12	0.27	0.12	0.27	0.17	0.42	0	N/A	0.05	0.331
FAT	2.28	0.54	2.13	0.57	2.07	0.59	**-0.15**	****0.014**	**-0.21**	****0.010**
Exhausted	0.72	0.61	0.64	0.61	0.58	0.66	-0.08	0.540	-0.14	0.338
Fatigued	0.74	0.69	0.70	0.65	0.71	0.66	-0.5	0.546	-0.03	0.766
Tired	1.05	0.56	0.95	0.58	0.83	9057	-0.10	0.269	-0.22	0.068
Drained	0.79	0.56	0.60	0.61	0.53	0.66	-0.19	0.021	-0.26	0.008

PWB= Positive Well Being, PD= Psychological Distress, FAT= Fatigue
** Before a p-value indicates that the results were statistically significant

Survey responses were also compared between the yoga and the control conditions (Table 9). PWB significantly improved overall (p=0.040), but there was no significant change between conditions 5 (p=0.065) and 65 minutes (p=0.323) post conditions compared to baseline. PD did not significantly differ between conditions (overall: p=0.399; 5 minutes: p=0.564; 65 minutes: p=0.365), but responses trended lower post yoga compared to the control. Similar to PD responses, FAT responses were not significantly different overall (p=0.714), at 5 (p=0.928) minutes post and 65 minutes (p=0.670) post yoga compared to the control condition. Figures 10-12 display mean changes in survey responses.

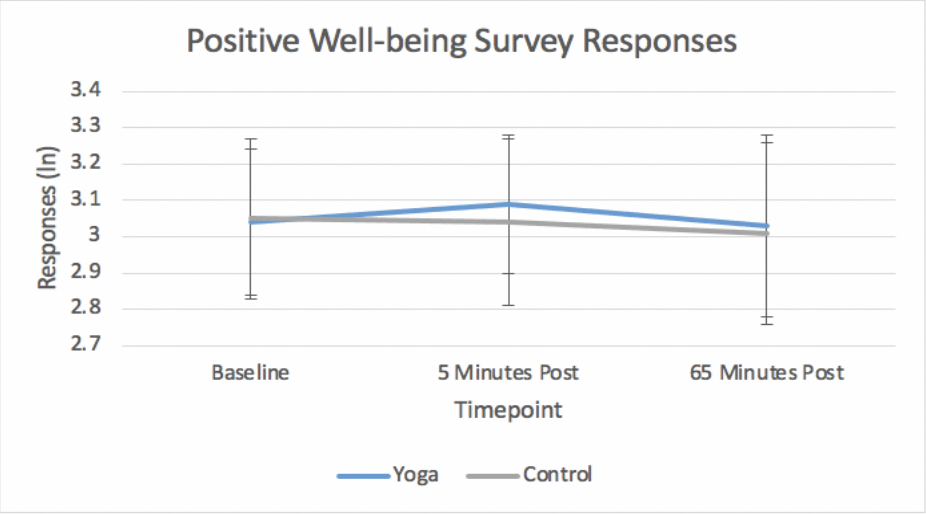

Figure 10 Positive Well-being Survey Responses between Conditions

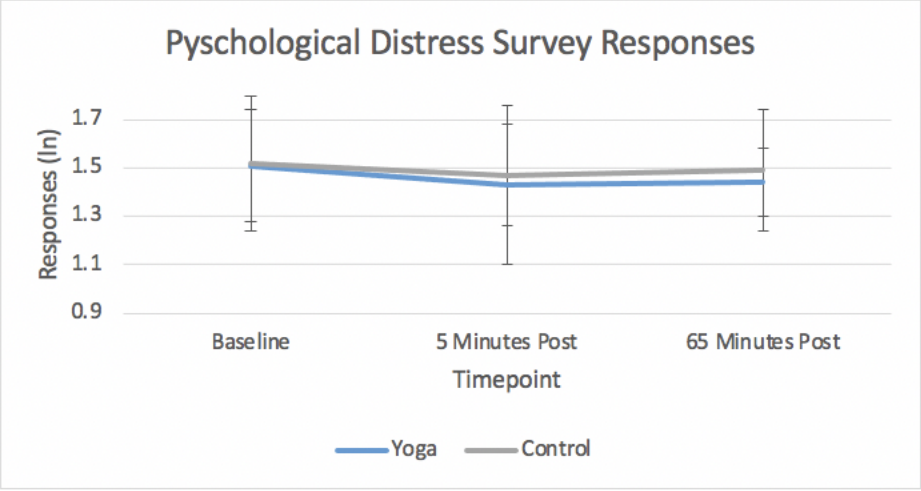

Figure 11 Pyschological Distress Survey Responses between Conditions

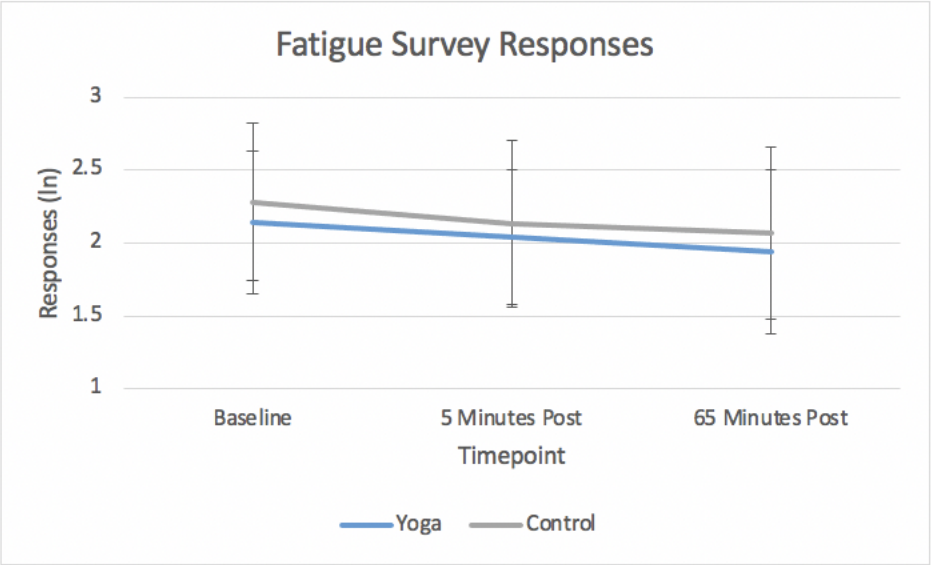

Figure 12 Fatigue Survey Responses between Conditions

Table 9 Comparison of SEES Survey Responses Between Conditions

Survey Outcomes Between Conditions (n=18)		
Factor	**Average Difference**	**p-value**
PWB		
Overall	0.92	**0.040
5 Minutes Post	2.29	0.065
65 Minutes Post	0.67	0.323
PD		
Overall	-0.29	0.399
5 Minutes Post	-0.27	0.564
65 Minutes Post	-0.03	0.365
FAT		
Overall	-0.02	0.714
5 Minutes Post	-0.01	0.928
65 Minutes Post	-0.04	0.670

** Before a p-value indicates that the results were statistically significant

5.0 Discussion

This study examined physiological [systolic blood pressure (SBP), heart rate (HR), and heart rate variability (HRV)] and psychological (survey) responses to a vinyasa yoga session compared to a control session. Overall compared to the seated control condition, yoga elicited the hypothesized and favorable response by decreasing SBP at both post condition timepoints compared to the seated control. Contrary to the hypotheses, HR and HRV demonstrated unexpected responses compared to the control, with HR increasing at both timepoints following the yoga condition compared to the control, and HRV decreasing following the yoga condition compared to the control condition. The exploratory aim of this study was to examine survey responses post yoga and control. Survey responses were found to have improved following both the yoga and control conditions. As hypothesized, there was greater improvements in survey responses including feelings of positive well-being (PWB), psychological distress (PD), and fatigue (FAT) occurring post yoga compared to baseline and compared to the control condition. Overall, an acute bout of vinyasa yoga was found to improve some cardiovascular responses, have adverse effects on other cardiovascular responses, improve feelings of PWB, and reduce feelings of PD/FAT.

The first aim of this study hypothesized that an acute bout of vinyasa yoga would improve the measured physiological responses by 65 minutes post yoga. At both post yoga timepoints (5 and 65 minutes), SBP decreased with a mean decrease of -3.5 mmHg at 5 minutes and a mean decrease of -0.5 mmHg at 65 minutes following the vinyasa yoga bout. One study by Pina et al., found not significant but similar SBP responses following a 60-minute bout of vinyasa yoga. This study found that SBP decreased by 1 mmHg compared to baseline values when measured

immediately post yoga.[63] Our findings are also consistent with SBP after an acute bout of exercise. As noted in previous sections, both aerobic[41,42] and resistance[42] exercise bouts have been found to generate a post exercise hypotensive response. Finally, blood pressure responses to this study's acute bout of vinyasa yoga are also consistent with a similar, larger body of evidence related to blood pressure responses to chronic yoga interventions. Wu et al., conducted a meta-analysis and concluded that long term (4-52 week) yoga interventions elicited moderate decreases in both systolic and diastolic blood pressure with there being greater reductions in SBP in yoga interventions that included breathing awareness.[64] This previous conclusion and the findings of our study are encouraging for improving blood pressure of Americans. Blood pressure is a risk factor of cardiovascular diseases (CVD) that can be easily measured.[2] As noted previously, vinyasa yoga is a mode of moderate intensity exercise,[6] but it is also a type of yoga that includes mindfulness and breathing components in addition to the physical postures. Previous studies have found improvements in ANS responses following interventions that only included breathing[28] and mindfulness conditions.[28,56] It can also be noted that vinyasa yoga is an accessible mode of exercise that requires minimal or no equipment. These factors indicate that vinyasa yoga is an effective method for improving blood pressure. Considering that there are three components of vinyasa yoga (physical poses, breathing, and mindfulness) future studies may further evaluate the blood pressure responses to the different components of vinyasa yoga.

Contrary to the heart rate related hypotheses, HR increased by an average of +6.6 bpm at 5 minutes post yoga and by +0.73 bpm at 65 minutes post yoga. Even though HR did not improve following the acute bout of yoga and compared to baseline measurements, HR trends post yoga displayed a linear decrease in HR responses (as displayed in Figure 6) with HR almost returning to baseline values at 65 minutes post yoga. Interestingly, HRV findings post yoga were mixed across HRV parameters. Standard deviation of normal-to normal R-R intervals (SDNN) decreased

by -0.13 ln 5 minutes after the yoga condition, but it increased from baseline by +0.05 ln at the 65 minute post yoga measurements. Root mean square of successive differences (RMSSD) decreased at both post yoga timepoints by -0.22 ln 5 minutes post yoga and by -0.01 ln 65 minutes post yoga compared to baseline values. High frequency (HF) HRV increased at both post yoga timepoints by +0.04 ln 5 minutes post yoga and by +0.25 ln at 65 minutes post yoga compared to baseline values. Typically, a lower resting HR indicates a better functioning heart, and a higher HRV indicates better functioning of the autonomic nervous system. Our resting results up to 65 minutes post yoga were mixed related to physiological functioning. Overall, post yoga HR and HRV responses conveyed no improvements in ANS functioning by 65 minutes following a vinyasa yoga session.

These HR and HRV findings are consistent with other studies that observed post exercise autonomic functioning changes. Esco et al. discovered that HRV measurements were still significantly reduced in subjects at least 28 minutes after 30-minute bouts of moderate intensity exercise.[44] Another study did find significant decreases in in HRV parameters immediately following three different exercise sessions of different intensities with the measurements returning to baseline or improving by 65 minutes post intervention.[47]. Our current study did not display significant improvements by 65 minutes post intervention; however, another study found that some HRV responses did not improve until 24 hours following an exercise bout. Gambassi et al., determined that RMSSD significantly improved 24 hours following a 25-minute moderate-intensity bout of exercise.[46] The findings of these and other studies have determined that exercise intensity and duration influence changes in autonomic functioning post exercise.[8,47] There are several potential reasons that the post yoga HR and HRV results of this study did not return to or surpass baseline values by 65 minutes post yoga. A longer period after exercise cessation may be necessary to see improvements in HR and HRV parameters considering that exercise

intensity/duration can impact autonomic functioning. Another explanation for these responses is that the vinyasa yoga sequence utilized as this study's intervention is an average of approximately 4 METs (i.e., moderate intensity) across the 60 minutes of the sequence.[6] Potentially, sections of the *Journey into Power*[61] yoga sequence may be of a higher, more vigorous intensity for some subjects indicating that a longer period post yoga may need to be observed to see significant improvements of HR/HRV parameters .Finally, the three different components that make up vinyasa yoga may have different impacts on HR/HRV responses post yoga that could generate different responses post yoga compared to a moderate intensity exercise session.

As previously noted, the blood pressure responses to yoga were favorable and as expected, and the and HR/HRV responses were contrary to the hypotheses. These opposing results indicate that blood pressure and HR/HRV may be predominantly influenced by different mechanisms. The ANS has been found to be a major influence of HR and HRV. The ANS constantly adjusts which branch (sympathetic or parasympathetic branch) has the most control over HR/HRV at any given moment; therefore, altering HR and HRV responses.[29] During exercise, the sympathetic branch is activated increasing HR and decreasing HRV. The parasympathetic branch is reactivated post exercise allowing HR to slowly decrease and HRV parameters to increase. [8,47] Blood pressure is also influenced by the ANS, but it has other proposed influences that are generated from an exercise bout. Positive vascular responses from exercise includes enhanced nitric oxide bioavailability (a potent vasodilator) and a decrease in the release of endothelin-1 and angiotensin-2 (vasoconstrictors). The increase in vessel diameter from these responses generates a decrease in pressure exerted against a vessel wall which lowers blood pressure and potentially reduces the impact of ANS effects on blood pressure. [65]

The second aim of this study hypothesized that SBP, HR, and HRV responses following a seated control condition would not change at both post condition timepoints. These hypotheses

were not observed with blood pressure increasing, HR decreasing, and HRV parameters increasing post seated control. Although not significant, there were increases in blood pressure by +4.8 mmHg at 5 minutes post control and an increase of +2.6 mmHg at 65 minutes post control. HR/HRV changes were all significantly different (HR was lower and HRV responses were higher) post control compared to the baseline measurements. The physiological responses to the seated control were not as hypothesized and not the main focus of this study, but they are worth noting as they strengthen the proposed idea that some cardiovascular responses may be differentially influenced. The HR/HRV responses to the seated control counter our hypothesized responses and the findings of a recent analysis related to acute and long-term sedentary behaviors. Bates et al. performed a meta-analysis to observe HR/HRV responses to acute bouts of prolonged sitting. No significant changes were found following a prolonged bout of sitting in these responses; however, the results trended toward slight increases in HR which counter the HR results of this study.[66] These responses were not observed in our study, but post seated condition blood pressure responses of our study are similar to typical prolonged seated blood pressure responses. A study by Alansare et al., found significant increases in blood pressure following a sedentary workday.[67] Lee et al., performed a systematic review and meta-analysis determining that long term sedentary behaviors have been found to be associated with increases in both systolic and diastolic blood pressure.[68]

As mentioned, the cardiovascular responses to the sedentary control in this study were not the hypothesized responses with the HR/HRV responses to the control condition being not what is typically observed in the literature. We know that the branches of the ANS influence HR/HRV via innervation of the sinoatrial (SA) node of the heart with sympathetic activations increasing HR and parasympathetic activation decreasing HR.[9] A speculated mechanism of these responses is that prolonged sitting may have generated strong reciprocal effects of the ANS branches, as the ANS branches act independently of each other. The longer subjects remained seated, there may

have been an almost complete withdrawal of sympathetic activity and significant increase in parasympathetic activity altering HR/HRV.

Although the HR/HRV responses to the seated control condition were not consistent with current evidence, the blood pressure responses to the seated control were typical responses as seen in the literature. Blood pressure changes can be influenced by ANS activity similar to how the ANS generates HR/HRV changes.[9] Another proposed mechanism for the increase in blood pressure is a reduction in nitric oxide availability from a sedentary bout.[69] As nitric oxide is a vasodilator, a reduction in it would increase vasoconstriction and potentially increase the pressure exerted on the artery wall (increase blood pressure). Blood pressure increases following a sedentary bout can also be influenced by reduced muscular demand, impaired vascular functioning, and reduced venous return in the lower limbs. These lower limb events can lead to reduced shear stress that generates vessel vasoconstriction (i.e., increased resistance/pressure).[70] A reduction in venous return occurs from sitting that leads to fluid accumulation in the lower limbs potentially increasing blood pressure.[71] Overall, the mechanisms for the physiological changes that occurred in the study need to be further evaluated.

The third aim of this study hypothesized that physiological responses post yoga would improve compared to responses to the seated control condition. SBP was significantly lower post yoga compared to the control condition, but HR/HRV responses did not confirm our hypotheses. HR did not improve by 65 minutes post yoga compared to the control condition. It was significantly lower (-11 bpm) at 5 minutes post and 65 minutes (-5 bpm) post control compared to post yoga. HRV significantly decreased overall post yoga compared to control at both post measurement timepoints.

The exploratory aim of this study hypothesized that positive and negative psychological responses to a 12-question survey would improve post yoga, not change post control, and display

significant improvements post yoga compared to the control. Many survey results were not significant, but they trended toward our hypothesis that survey responses would improve post yoga compared to baseline values and compared to the control condition Although not significant, the PD responses decreased at both timepoints (5 minutes: -0.08 on a logarithmic scale; 65 minutes: -0.07 on a logarithmic scale) post yoga compared to baseline values indicating that there was slightly less psychological distress after participating in vinyasa yoga. Similar to the PD responses, subjects answered with overall lower FAT values indicating that they had less feelings of fatigue post yoga and post control. PD/FAT responses were not significantly greater post yoga compared to the control.

The strengths of this study included consistent visit times, a standardized vinyasa yoga protocol, a randomized crossover design, an equal number of male and female subjects, subjects with diverse exercise backgrounds, including respiration rate during HRV recordings, and a controlled room temperature. All in-person visits were scheduled one week apart at the same time of day for each participant to minimize time of day and day of week physiological variations. A standardized vinyasa yoga protocol was utilized for the yoga condition of this study. The vinyasa yoga protocol for each subject was the same video demonstration with verbal voiceovers of the poses, mindfulness, and breathing cues. This study also included a randomized crossover design to potentially limit the influence of familiarization to the laboratory and equipment on the study outcomes. An equal number of males and females were recruited for this study generating a more diverse sample. The subjects also had diverse exercise backgrounds and previous yoga experience making the results of this study generalizable to the general yoga population. Previous studies that have included HRV measurements have not included respiration rate. Recording respiration rates during HRV recordings allows us to determine that the HF HRV measurement is a valid measurement of parasympathetic activity. Finally, room temperature (between 68-72 degrees

Fahrenheit) was maintained limiting potential physiological responses that occur from extreme temperatures.[72]

Although there were several strengths of this study, there were also several weaknesses that should be addressed. First, the Polar heart rate monitor was used to collect HR and HRV measurements due to feasibility. This monitor has been found to be a reliable measurement of HR and HRV;[73] however, the electrocardiogram (ECG) has been found to be a gold standard method for HR/HRV measurement.[58] Another weakness was that this study only included vinyasa yoga as the yoga protocol indicating that the results of this study are only reflective of the *Journey into Power* vinyasa yoga sequence and not any other yoga styles/sequences. The subjects recruited for this study all had experience participating in yoga, but the subject's yoga experience/weekly exposure varied across this study's sample. Chronic training adaptations may have occurred in the subjects with more yoga experience. A training adaptation in some of the subjects may have impacted the physiological outcomes of this study. This study occurred in a controlled setting with a standardized protocol indicating that these outcomes may differ when vinyasa yoga is practiced in a non-laboratory environment. Future studies should consider including a larger sample size, other styles of yoga, conditions measuring responses to the individual components of vinyasa yoga, a third exercise arm, other ANS responses that quantify sympathetic activity, and include time points of measurements beyond 65 minutes after the exercise intervention.

The findings of this study indicate that vinyasa yoga alters autonomic and cardiovascular functioning by decreasing SBP, increasing HR, and having mixed impacts to HRV measurements. There were additional unsuspected physiological outcomes following a seated control condition. An acute bout of vinyasa yoga also altered positive and negative feelings providing initial indications that vinyasa yoga may benefit mental health outcomes. Additional research is warranted for psychological effects of vinyasa yoga. Based on the results of this study, acute blood

pressure, HR, and HRV responses to vinyasa yoga may not be linked by the same mechanisms. Proper functioning of the ANS and cardiovascular system are necessary to maintain one's health; especially, to decrease the burden and prevalence of CVD's worldwide. This study contributes to the literature as little has been done to examine the effect of an acute bout of yoga on cardiovascular and autonomic function using rigorous yoga methods and a control condition. It also reveals that additional research on the components of vinyasa yoga and the mechanisms of blood pressure, HR, and HRV changes following yoga and bouts of prolonged sitting are necessary to better understand autonomic and cardiovascular responses to different activities.

Appendix A Phone Screening Script

Screening Call Script:

1) **Introduction:** *Thank you for calling to find out more about my research study. My name is _____ and I am a student researcher at the University of Pittsburgh. If it is okay with you, I would like to briefly tell you about the research study.*

2) **Description of Sessions:** *The purpose of this research study is to examine the effect of a vinyasa yoga session on measures of autonomic nervous system function including heart rate, systolic blood pressure, and heart rate variability. I am interested in recruiting 18 healthy adults between the ages of 18-55 who are able to perform and have experience with yoga. If you are found to be initially eligible during this call, I will have you schedule your virtual orientation session where I will describe to you the full description of the study, give you a chance to ask questions, and if you are interested in participating, you will be given the opportunity to sign the consent document. Next, I will ask you to perform 7 yoga poses to ensure that you have some yoga experience. At the end of the virtual orientation, I will ask you to schedule 2 visits where you will come into the Physical Activity and Weight Management Research Center at the University of Pittsburgh Oakland Campus. The first will include baseline measurements like your height, weight, and blood pressure. One of the visits will include you performing a 60-minute vinyasa yoga session, and the other visit will include you viewing a 60-minute documentary.*

3) Do you have any questions or concerns? Do you think that this research study might be something you would be interested in participating?
   a. If **NO**, *thank you for your interest in the study and have a great day* **[end call]**
   b. If **YES**, continue screening by determining eligibility.

4) **Determining Eligibility:** *To determine if you are eligible for this study, I will need to ask you a few questions about your demographics, physical health, and medical history. These questions will take approximately 5 minutes to be answered. If we complete this interview and I determine that you are initially eligible, I will ask for your contact information to provide you with a copy of your signed consent form and to confirm your future study visits. Then, I will have you schedule your virtual orientation and your two visits.*
The responses you give me to these questions will remain confidential. If I determine that you are ineligible, I will conclude the interview and destroy the paper with your responses following this call.

Do you have questions about anything that I have informed you about so far?
I will answer any questions that the individual has. If the individual wants to consider participation in the study, I will provide them with the phone number that they can contact me if they decide they would like to participate.

5) **<u>Verbal Consent to Continue:</u>** Do I have your permission to ask you these questions and your contact information?
    a. If **NO,** *thank you for your interest in the study and have a great day* **[end call]**
    b. If **YES,** complete information on the next page regarding verbal assent.

Verbal Assent Form

1) Did the caller give verbal permission to conduct questionnaires?
    a. YES _____
    b. NO _____

2) Verbal Assent was given to: _____
3) Date of Verbal Assent: _____

Screening Questions

1) What is your gender? _____

2) How old are you (**must be 18-55**)? _____

3) What is your date of birth? _____

4) Do you have any physical limitations (i.e., musculoskeletal injuries)?

   b) YES
   c) NO

   Explain: _____

5) Are you able to perform yoga poses?

   a. YES
   b. NO

6) Are you currently pregnant?

   a. YES
   b. NO

7) Has any medical professional ever told you that you had any of the following conditions?

   a. Heart Disease
      i. YES
      ii. NO
   b. Heart Attack
      i. YES
      ii. NO
   c. Angina
      i. YES
      ii. NO
   d. Hypertension
      i. YES
      ii. NO
   e. Stroke
      i. YES
      ii. NO
   f. Diabetes
      i. YES
      ii. NO
   g. Cancer
      i. YES
      ii. NO

8) Are you taking any medications?
    a. YES
    b. NO

    List any medications and what they treat: _____
    _____
    _____
    _____

Following Screening Questions:

- **Ineligible:** I will not collect individual's contact information or schedule their visits.
    - *It appears that you are not eligible for this study from the information that you provided me. I will destroy the forms with your information. Thank you very much for your interest and have a great day.*
- **Eligible:**
    - You appear to be eligible for this study based on your responses. I will now schedule your virtual orientation that will take approximately 20-30 minutes. I will also schedule your two session visits that will take approximately 2-hours. These visits will need to occur on the same day one week apart.

Eligible:

a. YES
b. NO

Orientation Date: _____

Visit 1 Date: _____

Visit 2 Date: _____

Contact Information

* To be completed only if individual appears eligible for the study

First name: _____

Last name: _____

Phone number: _____

Email: _____

Appendix B Vinyasa Session Data Sheet

Yoga Protocol Data Sheet

ID#:_____ Session #:_____ Date: _____

Height: #1_____ cm.#2_____cm. #3_____cm. Weight: #1_____ kg. #2_____kg. #3_____kg.

BMI:_____ Date of Birth: _____Age: _____ Gender: Male Female

***Ask the next three questions below at the first in-person visit only**

How often (in minutes) do you engage in physical activity weekly? _____

What kind of physical activity? _____

How many times per week do you participate in yoga? _____

Room Temperature: _____degrees F Average baseline BP: _____mmHg Average baseline HR: _____bpm

Time (minutes)	Activity	Heart Rate (bpm)	Blood Pressure (mmHg)	Asana 1			Asana 2			Asana 3		
0:00-1:00	Seated Rest											
1:01-2:00	Seated Rest											
2:01-3:00	Seated Rest											
3:01-4:00	Seated Rest											
4:01-5:00	Seated Rest											
5:01-6:00	Admin Survey/Take BP #1											
6:01-7:00	Take BP #2											
7:01-8:00	Seated Measure HR/HRV Recordin											

	g (1x, 6-minutes)											
8:01-9:00	Seated HR/HRV Recording											
9:01-10:00	Seated HR/HRV Recording											
10:00-11:00	Seated HR/HRV Recording											
11:01-12:00	Seated HR/HRV Recording											
12:01-13:00	Seated HR/HRV Recording											
0:00-1:00	Yoga			Childs pose	1	2	Down dog				1	2
1:01-2:00	Yoga			3 legged dog R	1	2	3 legged dog L				1	2
2:01-3:00	Yoga			Ragdoll	1	2	Mountain	1	2	3 Oms	1	2
3:01-4:00	Yoga			Sun A 1							1	2
4:01-5:00	Yoga			Sun A 2							1	2
5:01-6:00	Yoga			Sun A 3	1	2	Sun A 4				1	2
6:01-7:00	Yoga			Sun A 5							1	2
7:01-8:00	Yoga			Sun B 1							1	2
8:01-9:00	Yoga			Sun B 1							1	2
9:01-10:00	Yoga			Sun B 2							1	2
10:00-11:00	Yoga			Sun B 3							1	2
11:01-12:00	Yoga			Sun B 3							1	2
12:01-13:00	Yoga			Sun B 4							1	2
13:01-14:00	Yoga			Sun B 5							1	2
14:01-15:00	Yoga			Flip dog R	1	2	Side plank R				1	2
15:01-16:00	Yoga			Crescent lunge R	1	2	Crescent twist R				1	2
16:01-17:00	Yoga			Warrior II	1	2	Extended side angle				1	2
17:01-18:00	Yoga			Flip dog L	1	2	Side plank L				1	2
18:01-19:00	Yoga			Crescent lunge L	1	2	Crescent twist L				1	2

19:01-20:00	Yoga			Warrior II	1	2	Extended side angle				1	2
20:00-21:00	Yoga			Chair	1	2	Chair twist				1	2
21:01-22:00	Yoga			Forward fold	1	2	Crow				1	2
22:01-23:00	Yoga			Chair							1	2
23:01-24:00	Yoga			Chair twist	1	2	Forward fold				1	2
24:01-25:00	Yoga			Crow							1	2
25:01-26:00	Yoga			Eagle R	1	2	Eagle L	1	2	Eagle R	1	2
26:01-27:00	Yoga			Eagle L	1	2	Leg raise R				1	2
27:01-28:00	Yoga			Airplane R	1	2	Half moon R				1	2
28:01-29:00	Yoga			Leg raise L	1	2	Airplane L				1	2
29:01-30:00	Yoga			Half moon L	1	2	Dancer R				1	2
30:00-31:00	Yoga			Dancer L	1	2	Dancer R	1	2	Dancer L	1	2
31:01-32:00	Yoga			Tree R	1	2	Tree L				1	2
32:01-33:00	Yoga			Warrior II	1	2	Triangle R				1	2
33:01-34:00	Yoga			Wide leg fold	1	2	Pyramid R				1	2
34:01-35:00	Yoga			Twist triangle R	1	2	Warrior II				1	2
35:01-36:00	Yoga			Triangle R	1	2	Wide leg fold				1	2
36:01-37:00	Yoga			Pyramid L	1	2	Twist triangle L				1	2
37:01-38:00	Yoga			Locust 1	1	2	Locust 2				1	2
38:01-39:00	Yoga			Bow 1	1	2	Bow 2				1	2
39:01-40:00	Yoga			Camel 1	1	2	Camel 2				1	2
40:00-41:00	Yoga			Bridge	1	2	Wheel 1				1	2
41:01-42:00	Yoga			Wheel 2	1	2	Wheel 3				1	2
42:01-43:00	Yoga			Wheel 4	1	2	Wheel 5				1	2
43:01-44:00	Yoga			Wheel 6	1	2	Supine butterfly				1	2
44:01-45:00	Yoga			Happy baby	1	2	Boat				1	2
45:01-46:00	Yoga			Half pigeon R	1	2	Double pigeon R				1	2
46:01-47:00	Yoga			Half pigeon R							1	2

47:01-48:00	Yoga			Double pigeon L								1	2
48:01-49:00	Yoga			Frog								1	2
49:01-50:00	Yoga			Single leg R								1	2
50:00-51:00	Yoga			Single leg L								1	2
51:01-52:00	Yoga			Double leg ext	1	2	Table top					1	2
52:01-53:00	Yoga			Fish								1	2
53:01-54:00	Yoga			Shoulder stand								1	2
54:01-55:00	Yoga			Plow	1	2	Deaf man's					1	2
55:01-56:00	Yoga			Supine twist R								1	2
56:01-57:00	Yoga			Supine twist L								1	2
57:01-58:00	Yoga			Seated butterfly								1	2
58:01-59:00	Yoga			Savasana								1	2
59:01-60:00	Yoga			Roll to seat	1	2	3 Oms					1	2
0:00-1:00	Seated Rest												
1:01-2:00	Seated Rest												
2:01-3:00	Seated Rest												
3:01-4:00	Seated Rest												
4:01-5:00	Seated Rest												
5:01-6:00	Admin Survey/Take BP #1												
6:01-7:00	Take BP #2												
7:01-8:00	Seated Measure HR/HRV Recording (1x, 6-minutes)												
8:01-9:00	Seated HR/HRV Recording												
9:01-10:00	Seated HR/HRV Recording												
10:00-11:00	Seated HR/HRV Recording												
11:01-12:00	Seated HR/HRV												

	Recording											
12:01-13:00	Seated HR/HRV Recording											
11:01-60:00	Seated Desk Work											
0:00-1:00	Seated Rest											
1:01-2:00	Seated Rest											
2:01-3:00	Seated Rest											
3:01-4:00	Seated Rest											
4:01-5:00	Seated Rest											
5:01-6:00	Admin Survey/Take BP #1											
6:01-7:00	Take BP #2											
7:01-8:00	Seated Measure HR/HRV Recording (1x, 6-minutes)											
8:01-9:00	Seated HR/HRV Recording											
9:01-10:00	Seated HR/HRV Recording											
10:00-11:00	Seated HR/HRV Recording											
11:01-12:00	Seated HR/HRV Recording											
12:01-13:00	Seated HR/HRV Recording											

Average 5-minute post BP: _____mmHg Post HR: _____bpm

Average 65-minute post BP: _____mmHg Post HR: _____bpm

Comments:

Appendix C Yoga Sequence

Vinyasa Yoga Protocol

INTEGRATION
Child's pose, Downward facing dog *(10 breaths each)*
Right leg bend and open, Left leg bend and open, Ragdoll *(5 breaths each)*
Roll to Mountain pose, Hands to heart, 3 Oms

SUN SALUTATIONS
Sun Salutation A x 5, Sun Salutation B x 5 *(1 breath per pose except for the first Sun Salutation B, hold each pose 5 breaths)*

CRESCENT LUNGE SERIES
Flip dog right, Side plank right *(vinyasa to downward facing dog)*
Crescent lunge right, Crescent lunge twist right, Warrior 2, Extended side angle right
(5 breaths each, vinyasa and repeat on left side)
Thunderbolt chair, Thunderbolt chair twist right *(5 breaths each)*
Fingers to toes forward fold *(10 breaths)*
Crow *(5 breaths, vinyasa to downward facing dog)*
Downward facing dog, Thunderbolt chair, Thunderbolt chair twist left (*5 breaths each)*
Palms to toes forward fold *(10 breaths)*
Crow *(5 breaths, vinyasa to downward facing dog)*

BALANCING SERIES
Eagle *(right, left, right left)*
Standing leg raise right, Airplane, Half moon, Standing leg raise left, Airplane, Half moon, *(repeat sequence on left),*
Dancer's pose *(right, left, right, left),*
Tree *(right, left)(5 breaths each)*
(vinyasa through Sun salutation A to Downward facing dog)
Warrior 1 *(1 breath)*

STANDING/TRIANGLE SERIES
Warrior 2, Triangle, Side facing forward fold with a bind, Pyramid with a bind, Twisting triangle *(5 breaths each) downward facing dog, repeat on left side then vinyasa through Sun salutation A to downward facing dog, high push up, lower to floor)*

BACKBENDING SERIES
Locust x 2, Floor bow x 2 *(5 breaths each, 1 breath in-between poses)*
(Upward facing dog, Downward facing dog, 1 breath each)
Camel x 2 *(5 breaths each, vinyasa to downward facing dog, move to supine)*
Bridge x 1, Wheel x 6, Supine butterfly, Happy baby *(5 breaths each)*

(bring knees to chest, rock forward to a seated position)
Rock forward to seat, Boat *(5 breaths, vinyasa to downward facing dog)*

RESTORATIVE POSTURES
Half pigeon right, Double pigeon right, Half pigeon left, Double pigeon left
(10 breaths each, vinyasa to downward facing dog)
Frog, Seated single leg extension right, Seated single leg extension left, Seated forward bend, Table top, Fish, Shoulder stand, Plow, Deaf man's pose, Supine twist right, Supine twist left, Seated butterfly *(10 breaths each)*
Savasana, Roll to right side, Move to seated position, hands to heart center, 3 Oms

Appendix D Documentary Session Data Sheet

Documentary Session Data Sheet

ID#:_____Session #:_____ Date: _____

Height: #1_____ cm.#2_____cm. #3_____cm. Weight: #1_____ kg. #2_____kg. #3_____kg.

BMI:_____ Date of Birth: _____Age: _____ Gender: Male Female

***Ask the next three questions below at the first in-person visit only**

How often (in minutes) do you engage in physical activity weekly? _____

What kind of physical activity? _____

How many times per week do you participate in yoga? _____

Room Temperature: _____degrees F Average baseline BP: _____mmHg Average baseline HR: _____bpm

Time (minutes)	Activity	Heart Rate (bpm)	Blood Pressure (mmHg)	Comments
0:00-1:00	Seated Rest			
1:01-2:00	Seated Rest			
2:01-3:00	Seated Rest			
3:01-4:00	Seated Rest			
4:01-5:00	Seated Rest			
5:01-6:00	Admin Survey/Take BP #1			
6:01-7:00	Take BP #2			
7:01-8:00	Seated Measure HR/HRV Recording (1x, 6-minutes)			
8:01-9:00	Seated HR/HRV Recording			
9:01-10:00	Seated HR/HRV Recording			

10:00-11:00	Seated HR/HRV Recording			
11:01-12:00	Seated HR/HRV Recording			
12:01-13:00	Seated HR/HRV Recording			
0:00-1:00	Seated Documentary Viewing			
1:01-2:00	Seated Documentary Viewing			
2:01-3:00	Seated Documentary Viewing			
3:01-4:00	Seated Documentary Viewing			
4:01-5:00	Seated Documentary Viewing			
5:01-6:00	Seated Documentary Viewing			
6:01-7:00	Seated Documentary Viewing			
7:01-8:00	Seated Documentary Viewing			
8:01-9:00	Seated Documentary Viewing			
9:01-10:00	Seated Documentary Viewing			
10:00-11:00	Seated Documentary Viewing			
11:01-12:00	Seated Documentary Viewing			
12:01-13:00	Seated Documentary Viewing			
13:01-14:00	Seated Documentary Viewing			
14:01-15:00	Seated Documentary Viewing			
15:01-16:00	Seated Documentary Viewing			
16:01-17:00	Seated Documentary Viewing			
17:01-18:00	Seated Documentary Viewing			

18:01-19:00	Seated Documentary Viewing			
19:01-20:00	Seated Documentary Viewing			
20:00-21:00	Seated Documentary Viewing			
21:01-22:00	Seated Documentary Viewing			
22:01-23:00	Seated Documentary Viewing			
23:01-24:00	Seated Documentary Viewing			
24:01-25:00	Seated Documentary Viewing			
25:01-26:00	Seated Documentary Viewing			
26:01-27:00	Seated Documentary Viewing			
27:01-28:00	Seated Documentary Viewing			
28:01-29:00	Seated Documentary Viewing			
29:01-30:00	Seated Documentary Viewing			
30:00-31:00	Seated Documentary Viewing			
31:01-32:00	Seated Documentary Viewing			
32:01-33:00	Seated Documentary Viewing			
33:01-34:00	Seated Documentary Viewing			
34:01-35:00	Seated Documentary Viewing			
35:01-36:00	Seated Documentary Viewing			
36:01-37:00	Seated Documentary Viewing			
37:01-38:00	Seated Documentary Viewing			
38:01-39:00	Seated Documentary Viewing			

39:01-40:00	Seated Documentary Viewing			
40:00-41:00	Seated Documentary Viewing			
41:01-42:00	Seated Documentary Viewing			
42:01-43:00	Seated Documentary Viewing			
43:01-44:00	Seated Documentary Viewing			
44:01-45:00	Seated Documentary Viewing			
45:01-46:00	Seated Documentary Viewing			
46:01-47:00	Seated Documentary Viewing			
47:01-48:00	Seated Documentary Viewing			
48:01-49:00	Seated Documentary Viewing			
49:01-50:00	Seated Documentary Viewing			
50:00-51:00	Seated Documentary Viewing			
51:01-52:00	Seated Documentary Viewing			
52:01-53:00	Seated Documentary Viewing			
53:01-54:00	Seated Documentary Viewing			
54:01-55:00	Seated Documentary Viewing			
55:01-56:00	Seated Documentary Viewing			
56:01-57:00	Seated Documentary Viewing			
57:01-58:00	Seated Documentary Viewing			
58:01-59:00	Seated Documentary Viewing			
59:01-60:00	Seated Documentary Viewing			

0:00-1:00	Seated Rest			
1:01-2:00	Seated Rest			
2:01-3:00	Seated Rest			
3:01-4:00	Seated Rest			
4:01-5:00	Seated Rest			
5:01-6:00	Admin Survey/Take BP #1			
6:01-7:00	Take BP #2			
7:01-8:00	Seated Measure HR/HRV Recording (1x, 6-minutes)			
8:01-9:00	Seated HR/HRV Recording			
9:01-10:00	Seated HR/HRV Recording			
10:00-11:00	Seated HR/HRV Recording			
11:01-12:00	Seated HR/HRV Recording			
12:01-13:00	Seated HR/HRV Recording			
12:01-60:00	Seated Desk Work			
0:00-1:00	Seated Rest			
1:01-2:00	Seated Rest			
2:01-3:00	Seated Rest			
3:01-4:00	Seated Rest			
4:01-5:00	Seated Rest			
5:01-6:00	Admin Survey/Take BP #1			
6:01-7:00	Take BP #2			
7:01-8:00	Seated Measure HR/HRV Recording (1x, 6-minutes)			
8:01-9:00	Seated HR/HRV Recording			
9:01-10:00	Seated HR/HRV Recording			
10:00-11:00	Seated HR/HRV Recording			
11:01-12:00	Seated HR/HRV Recording			

12:01-13:00	Seated HR/HRV Recording			

Average 5-minute post BP: _____mmHg Post HR: _____bpm

Average 65-minute post BP: _____mmHg Post HR: _____bpm

Comments:

Appendix E Subjective Exercise Experience Scale

Subjective Exercise Experience Scale

How Do You Feel?

This inventory contains a number of items designed to reflect how you feel at this particular moment in time (i.e., Right Now). Please circle the number on each item that indicates **HOW YOU FEEL RIGHT NOW.**

I FEEL:

1. Great						
1	2	3	4	5	6	7
not at all			moderately			very much so
2. Awful						
1	2	3	4	5	6	7
not at all			moderately			very much so
3. Drained						
1	2	3	4	5	6	7
not at all			moderately			very much so
4. Positive						
1	2	3	4	5	6	7
not at all			moderately			very much so
5. Crummy						
1	2	3	4	5	6	7
not at all			moderately			very much so
6. Exhausted						
1	2	3	4	5	6	7
not at all			moderately			very much so
7. Strong						
1	2	3	4	5	6	7
not at all			moderately			very much so
8. Discouraged						
1	2	3	4	5	6	7
not at all			moderately			very much so
9. Fatigued						
1	2	3	4	5	6	7
not at all			moderately			very much so
10. Terrific						
1	2	3	4	5	6	7
not at all			moderately			very much so

11. Miserable

1	2	3	4	5	6	7
not at all			moderately			very much so

12. Tired

1	2	3	4	5	6	7
not at all			moderately			very much so

Appendix F Modifications list

High/Low Push up
M1-Knees to floor
M2-Lower all the way to floor

Flip Dog
M1-Reverse table top
M2- 3 legged dog with hip open

Side Plank
M1-On forearm
M2-Dropped knee

Crescent Twist
M1-Knee to floor

Extended Side Angle
M1-Elbow to Knee

Crow
M1-Feet on floor
M2-Squat

Wheel
M1-Head on floor
M2-Bridge

Floor Bow
M1-Locust pose
M2- Cobra

Camel
M1- Hands to low back

Happy Baby
M1-Grab back of legs instead of feet

Frog
M1-Child's pose

Locust
M1- Cobra pose

Shoulder stand
M1- Legs in the air

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