Chronic effects of Hatha yoga on heart rate variability and EEG spectral power in young adults with elevated mental health symptoms

by

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Abstract

More than 50% of adults will be diagnosed with a mental illness or disorder within their lifetime. There is a significant increase in the prevalence of internalizing disorders and associated symptomology (i.e., anxiety, depression, stress) for young adults ages 18 to 35 years compared to other age groups. Despite the increased prevalence of anxiety, depression, and stress symptoms in young adults, there remain significant barriers to mental health treatment. Given these alarming statistics, it is crucial to develop interventions aimed at reducing internalizing symptomology. Yoga is one form of physical activity that represents a non-traditional form of mental health treatment; both acute and chronic bouts of yoga have been shown to reduce mental health symptoms. Acute and chronic bouts of yoga also affect physiological markers including heart rate variability (HRV) and electroencephalography (EEG). However, the available studies in yogic literature are heterogeneous in terms of exercise characteristics (i.e., acute vs. chronic, frequency, intensity, time, types). Moreover, few studies have examined how changes in physiological markers relate to changes in participant-reported behavioral outcomes. Lastly, the methodological quality of the existing literature is poor and there is a need for greater rigor in the study design (e.g., inclusion of true and/or active control groups). Thus, the overarching purpose of this dissertation is to address these knowledge gaps by evaluating the effects of a 10-week (45-minute sessions, 2x/week) Hatha yoga intervention compared to a meditation intervention (active control) and true control group on physiological markers and mental health symptomology in young adults ages 18-35. Results from this dissertation revealed that both 10 weeks of Hatha yoga and meditation led to decreases in self-reported mental health symptoms, with meditation leading to significant reductions in depression, stress, and overall mental health

as indicated by the BDI, DASS-21 depression, stress, and total scores. Contrary to the study hypotheses, EEG-derived frontal alpha and theta power significantly decreased over time for all groups, and there were no significant changes in HRV indices. Nevertheless, these results have positive clinical implications for utilizing meditation as alternative or complementary mental health treatment for adults ages 18-35 experiencing elevated mental health symptoms.

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List of Abbreviations

BAI	Beck Anxiety Inventory
BDI	Beck Depression Inventory
DASS	Depression Anxiety and Stress Scale
EEG	Electroencephalography
HR	Heart Rate
HRV	Heart Rate Variability
Hz	Hertz
LF/HF	Low-Frequency High-Frequency Ratio
PNS	Parasympathetic Nervous System
RMSSD	Root Mean Square of Successive Differences
SDNN	Standard Deviation of Normal Sinus Beats

Chapter 1: Introduction

Section 1: Overview

More than 50% of individuals will be diagnosed with a mental illness or disorder within their lifetime (Center for Behavioral Health Statistics, 2021). Over the past decade, there has been an increase in the prevalence of mental health disorders from 18.5% to 30.6% from 2008 to 2020, including anxiety, depression, and somatic symptoms (Center for Behavioral Health Statistics, 2021; Hedden et al., 2015). Despite the increased prevalence of mental health symptomology, there remains a gap in access to services as 24.7% of adults in the United States report an unmet need for mental health treatment (Reinert et al., 2021). Acute and chronic yoga and meditation are accessible and alternative forms of mental health treatment that have reduced symptom presentation of anxiety (Albracht-Schulte & Robert-Mccomb, 2018; Elstad et al., 2020; Lemay et al., 2019; Shohani et al., 2018; Winroth et al., 2019), depression (Elstad et al., 2020; Lemay et al., 2019; Maddux et al., 2018; Papp et al., 2019; Shohani et al., 2018), and stress (Lemay et al., 2019; Maddux et al., 2018; Shohani et al., 2018). However, it is unclear whether changes in anxiety, depression, and stress symptoms are due to the *movement* associated with yoga practice or *meditative state* during acute and chronic yoga; indeed, no study has directly compared these modalities.

Physiologically, heart rate variability (HRV) and electroencephalography (EEG) have been shown to change in response to participation in yoga and meditation. Both frequency- and time-domain variables of HRV respond to acute and chronic bouts of yoga and meditation. Specifically, the frequency-domain variable of low-frequency high-frequency ratio (LF/HF) decreases after yoga (Chu et al., 2017; Hewett et al., 2019; Meshram & Meshram, 2019) and meditation (Nivethitha et al., 2017). Additionally, the time-domain variable of root mean square of successive differences (RMSSD) increases with participation in yoga (Albracht-Schulte & Robert-Mccomb, 2018; Meshram & Meshram, 2019) and meditation (Nazaraghaei & Krishna Bhat, 2020; Nivethitha et al., 2017). Moreover, previous research shows both alpha and theta EEG band power increase after yoga (Field et al., 2010) and meditation (Bhaskar et al., 2020; Harne & Hiwale, 2018). These changes seen in EEG power alpha and theta power bands after participation in yoga and meditation are indicative of active brain inhibition and increased cognitive control, respectively. To this note, the increases in active brain inhibition and cognitive control may indeed reflect increased mental relaxation. However, few studies have examined the physiological changes that may underlie the changes in internalizing symptoms due to participation in acute (Albracht-Schulte & Robert-Mccomb, 2018; Field et al., 2010) and chronic (Chu et al., 2017; Elstad et al., 2020; Hewett et al., 2019) yoga and meditation interventions.

The overarching purpose of this dissertation is to evaluate the effects of a 10-week yoga intervention compared to a meditation intervention on HRV, EEG, and internalizing symptoms in young adults ages 18-35 years. The LF/HF and RMSSD of HRV will be examined, and EEG alpha and theta power will be evaluated. Differences in anxiety, depression, and stress symptoms will also be examined. Additionally, secondary physical fitness measures will be assessed. This chapter will discuss key concepts and theoretical frameworks for the specific aims and hypotheses.

Section 2: Mental Health Symptomology

There is an increase in the prevalence of internalizing disorders and associated symptomology between the ages of 18 to 35 years compared to those 35 years and older (Goodwin et al., 2020; Van Loo et al., 2021). In the United States, the most recent estimates of the prevalence of anxiety and depression from 2019 are 19.5% (Terlizzi & Villarroel, 2019) and

21% (Villarroel & Terlizzi, 2019) respectively. In addition to those that meet diagnostic criteria for mental health disorders, 84.4%, 81.5%, and 49% of young adults exhibit subclinical symptoms of anxiety (Terlizzi & Villarroel, 2019), depression (Villarroel & Terlizzi, 2019), and stress (American Psychological Association, 2020). Given these alarming statistics, it is crucial to develop interventions aimed at reducing internalizing symptomology.

Traditional treatments include psychoactive medications, brain stimulation therapies, and psychotherapy (NIMH, 2022). While these forms of mental health treatments are widely used (NIMH, 2022), significant financial (i.e., lack of insurance coverage, high prescription costs; Coombs et al., 2021; Kullgren et al., 2012; Pabayo et al., 2021), sociocultural (i.e., stigma, cultural beliefs; Kullgren et al., 2012; MacDonald et al., 20200), and structural (i.e., limited access to mental health services, long wait times, and urbanization of facilities; Coombs et al., 2021; Kullgren et al., 2012) barriers are commonly reported. In addition, adverse side effects (Stroup & Gray, 2018), the concern of medication dependence (Malik et al., 2021), socioeconomic factors (e.g., social support, stigma, insurance, medication cost; Khalifeh & Hamdan-Mansour, 2021; Marrero et al., 2021), individual factors (e.g., patient literacy, religion, educational, low self-efficacy, co-morbid diagnoses; Khalifeh & Hamdan-Mansour, 2021; Marrero et al., 2020) and healthcare system factors (e.g., lack of medication information, accessibility to provider and/or pharmacy, provider/patient relationship; Khalifeh & Hamdan-Mansour, 2021) associated with pharmacological treatments may also reduce long-term adherence. Non-traditional treatments such as aerobic exercise, strength training, and participation in recreational physical activity (Chekroud et al., 2018; Parra et al., 2020) may help to address these barriers.

Section 3: Yoga as an Alternative Treatment

Yoga is one type of physical activity that addresses the financial and structural barriers encountered with traditional psychotherapy (Cramer et al., 2016). Indeed, over 20 million people in the US practice yoga, and over 30 million people have practiced yoga within their lifetime (Cramer et al., 2016; Field, 2016). Although there is a growing body of research specifically evaluating the physical and mental health benefits of yoga practice, additional research is necessary to quantify the physiological changes resulting from acute and chronic participation in yoga in young adults with clinical or subclinical levels of internalizing symptoms.

Yoga may be considered an effective health intervention, as there is a demonstrated improvement in the severity of chronic somatic pain (Sherman et al., 2005; Tekur et al., 2008), cardiovascular risk factors (Damodaran et al., 2002; Madanmohan et al., 2004; Manchanda et al., 2000), metabolic risk factors (Kristal et al., 2005; O'Keane et al., 2005; Sinha et al., 2007), cognitive function (Chattha et al., 2008; Oken et al., 2006), physical fitness (Berger et al., 2009; Hart & Tracy, 2008; Logghe et al., 2010), and severity of mental health symptoms (Chu et al., 2017; Elstad et al., 2020; Lemay et al., 2019; Maddux et al., 2018; Papp et al., 2019; Shohani et al., 2018; Telles et al., 2009; West et al., 2004). Moreover, Cramer et al., (2016) found that 76.4%, 84.7%, and 67.5% of individuals respectively, practiced yoga to improve overall well-being, alleviate stress, and feel better emotionally. Further, several studies have reported that yoga is effective in reducing depression (Chu et al., 2017; Elstad et al., 2020; Maddux et al., 2018; Papp et al., 2019; Shohani et al., 2018), anxiety (Lemay et al., 2019; Maddux et al., 2018; Shohani et al., 2018; Winroth et al., 2019), and stress (Chu et al., 2017; Lemay et al., 2019; Maddux et al., 2018; Shohani et al., 2018) symptoms.

However, these studies are heterogeneous in terms of acute vs. chronic participation and exercise characteristics (frequency, intensity, time, types). Moreover, few studies have examined potential physiological mechanisms or markers that may underlie changes in participant-reported behavioral outcomes. Furthermore, the methodological quality of the existing literature is lacking and there is a need for greater rigor in the study design and inclusion of true control groups and/or active control groups. To this end, behavioral measures have been widely used to evaluate the effect of both acute and long-term yoga interventions on mental health; however, as stated previously there is little research evaluating underlying mechanisms, specifically physiological mechanisms, or markers, associated with mental health symptoms and changes in such symptoms. Therefore, as the next logical step in yoga research, it is necessary to comprehensively evaluate potential physiological markers of internalizing symptoms in this population, and specifically in response to a long-term Hatha yoga intervention.

Section 4: Heart Rate Variability as a Physiological Marker of Internalizing Symptoms

Heart rate variability (HRV) measures the autonomic nervous system (ANS) influence on the central nervous system (CNS) in response to physiological, psychological, and behavioral states (Laborde et al., 2017; Shaffer & Meehan, 2020). Thayer and Lane (2000) posit that the ANS and anterior executive region of the brain work complementary to each other in regulating HRV. HRV can be used as an index of central-peripheral integration (as indexed by the LF/HF ratio and RMSSD), which details the relationship between the brain and the physical manifestation of internalizing symptoms. Wrist and chest-worn heart rate (HR) monitors are accessible and provide reliable measurement tools to evaluate HRV (Laborde et al., 2017). To obtain a reliable short-term resting HRV measurement, the suggested minimum sampling rate is 500Hz, with a recording duration between 1-5 minutes, and the participant is in a seated position, with both feet flat on the ground and hands resting on the thighs. Reliable and valid short-term resting HRV recordings provide information on time-domain and frequency-domain variables

(Laborde et al., 2017; Rajbhandari Panday & Panday, 2018; Shaffer & Venner, 2013) which index overall vagal tone, parasympathetic input, or overall physiological relaxation (Laborde et al., 2017).

RMSSD is a time-domain variable that reflects vagal tone and is comparatively absent of respiratory influence (Laborde et al., 2017). The values of RMSSD reflect beat-to-beat differences and index estimated vagal-mediated changes in overall HRV (Shaffer & Ginsberg, 2017). An increase in RMSSD represents an increase in parasympathetic input which is associated with greater cardiac health (Shaffer & Ginsberg, 2017) and increased efficiency of emotional regulation (Williams et al., 2015). LF/HF is a frequency-domain variable that similarly indexes vagal tone (Shaffer & Ginsberg, 2017) with an estimation of both sympathetic and parasympathetic input (Laborde et al., 2017; Shaffer & Ginsberg, 2017). A high LF/HF ratio indicates sympathetic dominance, parasympathetic withdrawal, and a fight-or-flight, inflexible behavioral response, while a low LF/HF indicates parasympathetic dominance, sympathetic withdrawal, and a tend-and-befriend, flexible behavioral response (Shaffer & Ginsberg, 2017). A tend-and-befriend response would be direct attending to stressors and the seeking of nurturing and positive connections in response to stressors (Shaffer & Ginsberg, 2017). This response would be considered a behaviorally flexible response as the individual is positively adapting to internal and external stressors and shifting attention and cognitive control to a different environmental construct (Brown & Tait, 2010).

Section 4.1: HRV and Yoga

Few studies have comprehensively evaluated the effects of yoga (Chu et al., 2017; Hewett et al., 2019; Meshram & Meshram, 2019) and mediation (Nivethitha et al., 2017) on HRV in those with mental health symptoms. Acute bouts of yoga (i.e., 90 minutes (Albracht-

Schulte & Robert-Mccomb, 2018)) and meditation (i.e., 5 minutes (Nivethitha et al., 2017), exhibited increases in RMSSD (Albracht-Schulte & Robert-Mccomb, 2018; Nivethitha et al., 2017) indicating high vagal tone and behavioral flexibility to internal and external stressors (Laborde et al., 2017; Thayer & Lane, 2000). Moreover, chronic bouts of yoga (i.e., 2 sessions/week, 60 minutes/session for 12 weeks (Chu et al., 2017); 2 sessions/week, 85 minutes/session for 12 weeks (Elstad et al., 2020); 5x/week, 35 minutes/session for 6 months (Meshram & Meshram, 2019)) and meditation (i.e., 3 sessions/week, 60 minutes/session for 3 months (Nazaraghaei & Krishna Bhat, 2020)) exhibited decreased LF/HF (Chu et al., 2017; Meshram & Meshram, 2019) and increased RMSSD (Elstad et al., 2020; Meshram & Meshram, 2019).

These changes following participation in both acute and chronic yoga and meditation indicate a shift toward parasympathetic-modulated vagal tone which translates to behavioral flexibility (Laborde et al., 2017; Thayer & Lane, 2000) and decreased internalizing symptoms of depression (Koch et al., 2019), anxiety (Thayer et al., 1996; Williams et al., 2015), and stress (Kim et al., 2018). While there is evidence of parasympathetic dominance because of participation in acute and chronic yoga and meditation, there are limitations to the current body of literature. These limitations include heterogeneity of acute vs. chronic participation and intervention characteristics (frequency, intensity, time, types). Additionally, there is a need for higher-quality study design and the inclusion of a control and/or active control group.

Section 5: EEG as a Physiological Marker of Internalizing Symptoms

Electroencephalography (EEG) is a visual representation of the electrical activity of populations of cortical pyramidal neurons. Differences in electrical activity reflect post-synaptic potentials (Constant & Sabourdin, 2012; Jackson & Bolger, 2014; Olejniczak, 2006; Teplan,

2002) typically elicited in the lab by the presentation of a stimulus during a motor or attention task. Although traditionally, wet electrodes are used in research settings, dry electrodes via portable EEG systems have become an area of increased study due to the ability to collect EEG data during ecologically valid tasks (Casson, 2019; Cho, 2017; Choktanomsup et al., 2017; Hunkin et al., 2021; Krigolson et al., 2021; Pu et al., 2021). EEG headsets are one type of portable EEG system shown to be feasible for research data collection (Krigolson et al., 2017, 2021; Pu et al., 2021). Continuous EEG can be collected from dry electrode portable EEG systems. Continuous EEG is decomposed using Fourier transformation (frequency-domain analyses) into constituent sinusoidal waves of different frequencies ranging from 0.5 to 100 hertz (Hz) (Constant & Sabourdin, 2012; Teplan, 2002). The amount of power in each frequency band is extracted as follows: delta (0.5 - 3 Hz), theta (4 - 7 Hz), alpha (8 - 12 Hz), beta (13 - 30 Hz), and gamma (40+ Hz) (Constant & Sabourdin, 2012; IMotions, 2017; Voytek, 2018). Greater EEG spectral power or overall neurological electrical activity is observed at rest in the theta band, while there is less EEG spectral power in the alpha band in individuals with anxiety (Betrouni et al., 2022) and OCD (Pogarell et al., 2006) compared to those with no mental health diagnoses, or control at rest. To this end, the present dissertation will evaluate resting-state EEG power as a function of chronic participation in yoga compared with meditation and control.

Section 5.1: EEG and Yoga

There has been a handful of research studies evaluating changes in resting-state EEG spectral power of healthy adults as a response to participation in yoga (Field et al., 2010; Kamei et al., 2000), meditation (Bhaskar et al., 2020; Harne & Hiwale, 2018; Stapleton et al., 2020), and yogic breathing (Bhaskar et al., 2020; Telles et al., 2017). Increases in theta band power (Field et al., 2010; Kamei et al., 2000) and alpha band power (Kamei et al., 2000) in response to yoga have been exhibited. Similarly, participation in meditation led to increases in theta band (Bhaskar et al., 2020; Harne & Hiwale, 2018) and alpha band power (Stapleton et al., 2020). There were, however, variable responses as a function of participation in yogic breathing practices in which there were increases (Bhaskar et al., 2020) and decreases (Telles et al., 2017) in both theta and alpha band power. While there is evidence of changes in alpha and theta band power as a function of yoga and meditation, there are no recent studies evaluating the effects of chronic yoga, meditation, or yogic breathing interventions on EEG band power. Like the available research on HRV and yoga, there is a lack of rigor in study design and overall methodology, a need for comparison to a true or active control group, and a lack of homogeneity of intervention characteristics (frequency, intensity, time, types).

Section 6: Specific Aims and Hypotheses

Bearing in mind the present limitations in the literature reviewed in this chapter, there are clear knowledge gaps that need to be addressed to understand the physiological changes as a parameter of mental health in response to acute *and* chronic yoga. Further, there is a need to comprehensively evaluate the relationship between subclinical mental health symptomology and RMSSD and LF/HF of HRV, as well as EEG alpha and theta band power.

The proposed study will address the present knowledge gaps by examining the relationship between yoga and meditation, subjective measurements of depression, anxiety, and stress symptomology, HRV, and EEG, and the relationships between these factors in young adults (i.e., ages 18-35) experiencing mental health symptomology (i.e., depression, anxiety, and stress). To this end a randomized control trial will be conducted, comparing a 10-week, 45-minute twice-a-week Hatha yoga intervention to meditation and controls. In this dissertation, 45 participants, ages 18-35 years, will be recruited to participate. Participants will be randomized into one of three groups (i.e., 15 participants per group); and repeated measurements will be collected throughout the 10-week intervention. A repeated measures analysis of variance (rm-ANOVA) with a between and within subjects' factor will be conducted to examine the following specific aims and hypotheses.

Specific Aim 1: Evaluate the efficacy of a 10-week Hatha yoga intervention on depression, anxiety, and stress symptoms compared to meditation and control.

- H1: The 10-week Hatha yoga intervention will lead to significant reductions in depression, anxiety, and stress as measured by the BDI, BAI, and DASS-21. Depression, anxiety, and stress symptoms will be significantly lower following the Hatha yoga and meditation intervention compared to the control.

Specific Aim 2: Evaluate the effects of a 10-week Hatha yoga intervention on inhibitory and cognitive control as measured by increased alpha and theta EEG band power, respectively, compared to meditation and control.

- H2: The 10-week Hatha yoga intervention will lead to significant increases in inhibitory and cognitive control as measured by increased alpha and theta band power, respectively. The Hatha yoga and meditation groups will exhibit significantly higher cognitive and inhibitory control as measured by alpha and theta band power compared to the control group after the 10 weeks.

Specific Aim 3: Evaluate the efficacy of a 10-week Hatha yoga intervention on parasympathetic dominance and behavioral flexibility as measured by LF/HF and RMSSD compared to meditation and control.

- H3: The 10-week Hatha yoga intervention will lead to parasympathetic dominance and behavioral flexibility as measured by a significant increase in RMSSD and a significant decrease in LF/HF. The Hatha yoga and meditation groups will exhibit parasympathetic dominance and behavioral flexibility as measured by a significantly higher RMSSD and lower LF/HF compared to the control group.

While the present dissertation will address the knowledge gaps in the yogic literature, the results may also have clinical implications for utilizing Hatha yoga as a complementary or potential alternative to traditional mental health treatment. Moreover, the findings from this study may enable clinicians to utilize HRV and EEG as physiological markers of mental health symptomology with traditional subjective measurements of mental health such as the BAI, BDI, and the DASS-21.

Section 7: Limitations and Delimitations

One limitation of the proposed study is that both EEG and HRV measurements will be taken in a resting state, which warrants a silent and dark space. As the laboratory space is in a shared building, with access to the outside, noise from other laboratories or light and noise from the outside may prevent the testing from being silent and dark. To delimit the possibility of disruption of resting-state data collection, the proposed study will block the windows with butcher paper and hold sessions at the start of sundown to reduce the light from the outside. Additionally, testing signs will be placed on the doors, and notices to other laboratories will be sent out to prevent any noise or disruptions.

Another limitation is the use of monetary incentives for self-selected participation. While monetary incentives have been shown to reduce dropout in research studies (Guyll et al., 2003), these incentives may be enabling participants with social-related anxiety to continue their participation in group sessions. Further, the monetary incentive may mask the incentive to participate to reduce mental health symptoms. Thus, it is possible that their self-reported measures of mental health will not reflect a reduction in symptoms, but rather an increase in stress and anxiety-related symptoms. However, the proposed study will address self-selection bias by including an exit interview upon post-testing to determine the number of participants that may have disregarded any social-related anxiety for the monetary incentive, as well as the number of participants that may have preferred smaller group or one-on-one sessions instead of group sessions.

The proposed study includes self-report subjective measures of mental health (i.e., BAI, BDI, DASS), which may result in self-report bias. While this study is not solely a self-report study, the subjective measurements of mental health will be used as variables in data analysis, therefore limiting self-report bias is important for ensuring a high quality of research and results. Hunt et al., (2003) demonstrated a reduction of reporting bias by disguising the purpose of the BDI, but there has been no current research employing this method, nor finding effective methods to reduce reporting bias. Thus, the proposed study will attempt to limit self-report bias by ensuring privacy and confidentiality to the participants while they are completing the mental health measures. Additionally, the BAI, BDI, and DASS-21 (Brown et al., 1997; Serpas & Ignacio, 2021; Zanon et al., 2021) have shown high internal validity and reliability across multiple populations.

While the MUSE EEG system has been validated (Krigolson et al., 2017, 2021) there are limitations to using the MUSE system that must be considered. The MUSE system utilizes two frontal electrodes, two temporal electrodes, and a frontal reference electrode, which have been shown to lose connection or fail to connect during data collection due to head shape, head size, and hairstyles (Krigolson et al., 2017), which could result in a loss of continuous EEG data, therefore affecting the quality and quantity of data collected. To address these potential limitations participants will be advised to style their hair away from the front of their face and their ears, if possible, to increase connectivity. Additionally, researchers and research assistants will utilize athletic pre-wrap to assist with the fit of the headband on participants whose MUSE is intermittently connecting or failing to connect. Lastly, researchers and research assistants will connect each MUSE headband one at a time and check the connection before data collection to ensure a stable connection before data collection.

This study is limited to young adults, aged 18-35 experiencing and concerned about elevated mental health symptoms. Study enrollment will also be open to young adults currently enrolled in a college or university or residing in the surrounding Auburn/Opelika area. Lastly, any young adults healthy to participate in physical activity and those without any intellectual or developmental disability will have the opportunity to participate in the present study.

Chapter 2: Literature Review

Section 2.1: Yogic Literature

The earliest known writings of yoga date back to the Vedas, a spiritual Hindu text. In the Vedas, yoga is defined as coming, joining, or yoking together (Stephens, 2010). The Upanishads were written following the Vedas and were a spiritual set of texts that elaborated on the essence of yoga (Michaels, 2004), as well as referenced yogic anatomy (i.e., chakras, udanas, pranas, samanas, apanas, and vyanas) (Stephens, 2010). The *Bhagavad Gita* was written as a part of the Upanishadic movement and within this historical story, the three yoga paths are introduced and applied to living a spiritual and fulfilling life. These three paths are: karma yoga or the yoga of service, jhana yoga, or the yoga of knowledge, and bhakti yoga, or the yoga of devotion (Patel, 2003; Prabhavananda & Isherwood, 1944; Stephens, 2010). Asanas or postures and pranayama or breath were first introduced in the *Yoga Sutras* written by Patanjali (Patel, 2003; Stephens, 2010). Patanjali identifies yoga as a spiritual and meditative way to reach self-enlightenment (Chennakesavan, 1992; Coward, 1985; Garfinkel & Schumacher, 2000; Malhotra, 2001; Shruti & Prasad, 2020). Additionally, within this text, both raja yoga also known as “royal yoga” and the 8-limbed path are introduced (Patel, 2003; Stephens, 2010). While practicing yoga, the 8-limbed path is to be followed to reach self-fulfillment and includes yama, niyama, asana, pranayama, pratyahara, dharana, dhyana, and samadhi (Bayley-Veloso & Salmon, 2016; Cramer et al., 2016; Field, 2011; Govindaraj et al., 2016; McCall, 2014; Patel, 2003; Stephens, 2010). Despite the many transitions in the types of yoga practiced over the past few decades, the 8 limbs of yoga are both observed and taught today (Bayley-Veloso & Salmon, 2016).

Hatha yoga is the most common type of yoga taught and practiced (Gothe & McAuley, 2016; Grabara & Szopa, 2015; Rachiwong et al., 2015; Vanfraechem et al., 2014). Hatha translates to sun and moon and heavily focuses on utilizing posture work to seal the soul or bind the spirit with movement (Burley, 2000; Stephens, 2010). There are other forms of yoga practiced today that incorporate the fundamentals of Hatha yoga through a combination of asana (yoga poses) and pranayama (breathing techniques) (Bayley-Veloso & Salmon, 2016). Other types of yoga commonly practiced today are Ananda, Anusara, ashtanga, Bikram, Integral, Iyengar, kundalini, and Sivananda (Patel, 2003; Stephens, 2010). While postures and breath are common across the different types of yoga, they all have specific characteristics and fundamentals of practice, which are described in Table 1. For the present dissertation, Hatha yoga will refer to the practice of physical asanas while maintaining continuous breath. Additionally, in the Hatha yoga sessions, sun salutations will be instructed to move between certain poses.

Table 1. *Characteristics And Fundamental Components of Various Forms of Yoga*

Yoga Type	Practice Fundamentals	Unique Characteristics
Ananda Yoga (Patel, 2003; Stephens, 2010)	Classical style of Hatha yoga using asana, pranayama, and meditation.	Attention on relaxation and safe asana work. This practice encourages adaptations to asanas. Silent meditative affirmations are often interwoven into practice.
Anusara Yoga (Patel, 2003; Stephens, 2010)	Heart oriented/centered asanas. Usually gentle, restorative flow.	God is kept at the center of the practice and the purpose of performing the asanas is align oneself with the flow of grace.
Ashtanga Yoga (Govindaraj et al., 2016; Patel, 2003; Stephens, 2010)	Movement through continual asanas and set sequences of asanas.	Grounded in the *Yoga Sutras*, practice includes using ujjayi breathing and is a form of highly focused yoga. Ashtanga yoga is said to eliminate toxins, increase energy and well-being, enhance circulation, flexibility, stamina, balance, and coordination. Includes different levels of series (primary, intermediate, and advanced).
Bikram Yoga (Bayley-Veloso & Salmon, 2016; Patel, 2003; Stephens, 2010)	Classical style of Hatha yoga using asana, pranayama, and meditation.	Yoga is practiced in a room anywhere from 80 to 105 degrees F. Practicing in heated temperatures is said to detoxify the body and lead to a better cardiovascular workout. Contemporarily called "hot yoga".

Integral Yoga (Patel, 2003; Stephens, 2010)	Primarily utilizes mediation and pranayama with asanas. Considered two separate movements with the goal of integrating different yoga paths into one.	Considered far beyond physical practice as this yoga incorporates meditation, mantra, service, devotions, and deep study.
Iyengar Yoga (Field, 2011; Garfinkel & Schumacher, 2000; Patel, 2003; Stephens, 2010)	Classical style of Hatha yoga using asana, pranayama, and meditation.	Main goal is to achieve PRECISE alignment of body position and to practice a strong control or practice of asanas. The focus is on the physical aspect and use of props is common to help practicing individuals achieve the "perfect pose".
Kripalu Yoga (Garfinkel & Schumacher, 2000; Patel, 2003; Reinhardt et al., 2018; Stephens, 2010)	Primary focus on pranayama with secondary focus on asanas and mindfulness.	Meaning "compassion" or "mercy", the practice is to coordinate breath with aligned movement so that there are easy transitions from one posture to another.
Kundalini Yoga (Bayley-Veloso & Salmon, 2016; Coward, 1985; Garfinkel & Schumacher, 2000; Patel, 2003; Stephens, 2010)	Related to classical Hatha style of yoga in which there is much less focus on asanas and a more targeted focus on pranayama, mantras, and meditation.	By connecting breath and physical movements, the practice aim is to awaken the body's chakras starting at the base of the spine. The practicing of mantras in Kundalini yoga includes chanting and singing as well as phrase repetition.
Power Yoga (Birch, 1995, 2000; Stephens, 2010)	Vigorous asanas drawn from traditional ashtanga practice.	This practice is a detachment from traditional yoga with the appeal primarily to fitness focused individuals. The asanas taught can be and are often modified. There is some emphasis on spiritual philosophy and meditative bliss.
Sivananda Yoga (Patel, 2003; Stephens, 2010)	Style of Hatha yoga that stresses the physical application of yoga and follows 5 yogic principles: classic asana practice, pranayama, meditation, relaxation, and proper diet.	This style of yoga incorporates full yogic breathing as well as the 4 principle yogic paths of jhana, bhakti, karma, and raja yoga. This is also one of the largest schools of yoga.

Today, more than 20 million individuals practice yoga in the United States, with 30 million having practiced yoga at some point in their lifetime (Cramer et al., 2016). Cramer et al., (2016) found that 66.1% and 29.3% of individuals practiced yoga to improve their energy levels and athletic or sports performance respectively. Further, Field et al., (2011) conducted a literature review on yoga interventions and found that yoga interventions as a physical fitness and health modality target improvements in flexibility (Amin & Goodman, 2014; Polsgrove et al., 2016; Vanfraechem et al., 2014), balance (Gothe & McAuley, 2016), and functional fitness (Gothe & McAuley, 2016; Ni et al., 2014; Noradechanunt et al., 2017; Rachiwong et al., 2015; Shiraishi & Bezerra, 2016). Indeed, the review showed statistically significant increases in flexibility (Amin & Goodman, 2014; Gothe & McAuley, 2016; Grabara & Szopa, 2015; Polsgrove et al., 2016; Rachiwong et al., 2015; Vanfraechem et al., 2014), balance (Gothe & McAuley, 2016), and overall functional fitness (Gothe & McAuley, 2016; Ni et al., 2014; Noradechanunt et al., 2017; Shiraishi & Bezerra, 2016).

It is evident that yoga as a physical activity and fitness modality is common and effective (Cramer et al., 2016; Field, 2011); however, it is equally important to evaluate yoga as a health modality to determine the effects of participation in yoga on mental health symptoms. To this point, Cramer et al., (2016) found that 84.7%, 78.4%, and 67.5% of individuals practiced yoga to reduce their stress levels, improve general wellness, and feel better emotionally, respectively. In the current body of literature, yoga has been shown to reduce symptoms of depression (Chu et al., 2017; Elstad et al., 2020; Lemay et al., 2019; Maddux et al., 2018; Papp et al., 2019; Shohani et al., 2018), anxiety (Albracht-Schulte & Robert-Mccomb, 2018; Elstad et al., 2020; Field et al., 2010; Lemay et al., 2019; Shohani et al., 2018; Winroth et al., 2019), and stress (Chu et al., 2017; Maddux et al., 2018; Shohani et al., 2018; Xu et al., 2021). The yoga interventions in these studies ranged from 4 weeks (Shohani et al., 2018) to 6 months (Meshram & Meshram, 2019) and included Hatha yoga (Chu et al., 2017; Shohani et al., 2018), vinyasa yoga (Elstad et al., 2020; Lemay et al., 2019), Bikram yoga (Hewett et al., 2017), power yoga (Maddux et al., 2018), high-intensity yoga (Papp et al., 2019), ethical yoga education (Xu et al., 2021), and unspecified types of yoga (Meshram & Meshram, 2019).

Current literature evaluating the effects of acute bouts of yoga on psychological outcomes is sparse, yet the results from these studies show a significant effect of yoga on mental health outcomes. More specifically, Winroth et al., (2018), Albracht-Schulte & Robert-McComb (2018), and Field et al., (2010) all reported participant decreases in self-reported anxiety following an acute bout of yoga. These bouts of yoga were 20 minutes (Field et al., 2010), 60 minutes (Winroth et al., 2019), and 90 minutes (Albracht-Schulte & Robert-Mccomb, 2018) in duration and implemented yin yoga (Winroth et al., 2019), YogaFit (Albracht-Schulte & Robert-Mccomb, 2018), and an unspecified form of yoga (Field et al., 2010). While Winroth et al., (2018) and Field et al., (2010) provide evidence of acute bouts of yoga leading to decreases in experienced mental health symptoms, they are not without their limitations. Methodologically, Winroth et al., (2018) and Field et al., (2010) did not directly compare yoga to a control or active control group. Yoga and tai-chi were confounded in the Field et al., (2010) study such that the yoga practice and tai-chi were practiced in the same 20-minute session, with no separation of either practice (Field et al., 2010). Additionally, Winroth et al., unequally compared yin yoga to aerobic exercise, comparing 30 participants in the yoga group to 14 participants in the aerobic exercise group; thus, these results must be carefully interpreted. Lastly, all three acute studies did not follow up or compare the forms of yoga over time, therefore, the long-term effects are unknown.

There are a handful of studies that have evaluated the effects of yoga over time on mental health outcomes (Chu et al., 2017; Elstad et al., 2020; Hewett et al., 2019; Lemay et al., 2019; Maddux et al., 2018; Papp et al., 2019; Shohani et al., 2018). Chu et al., (2017), Shohani et al., (2019), and Papp et al., (2019) all evaluated the effects of long-term Hatha yoga interventions on mental health. Chu et al., (2017) implemented a 12-week Hatha yoga intervention (60-minute sessions, 2x/week) comparing pre-test and post-test BDI and perceived stress scale (PSS) scores between a Hatha yoga group (n = 13; M age = 33.08 ± 9.11 years) and waitlist control group (n = 13; M age = 32.38 ± 8.27 years). Participants were all female and exhibited mild to moderate depression symptoms indicated by a score of 14-28 on the BDI. Results indicated a significant decrease in BDI from pre-test to post-test for the Hatha yoga group, but not the control group (Chu et al., 2017). These results are further supported by the findings in the Shohani et al., (2019) study. Shohani et al., (2019) implemented a 4-week (60-70-minute sessions, 3x/week) Hatha yoga intervention among 52 females (M age = 33.5 ± 6.5). The study design was a single group pre/post design measuring mental health via the Depression, Anxiety, and Stress Scale-21 (DASS-21). Results showed a significant decrease in depression, anxiety, and stress scores from pre- to post-test because of participation in the Hatha yoga intervention (Shohani et al., 2018).

Papp et al., (2019) however, reported conflicting results from that of Chu et al., (2017) and Shohani et al., (2018). The RCT compared a 6-week high-intensity Hatha yoga intervention (60-minute sessions, 1x/week; N = 21) to a typical control (N = 23). Depression and anxiety were measured via the Hospital Anxiety and Depression Scale (HADS) and stress was measured via the PSS (Papp et al., 2019). There were no significant differences between the HADS and PSS scores of the yoga group and control group following the 6-week intervention, however, there was a dose effect for depression scores, in that those who practiced both in-person and at home exhibited a significant decrease in depression scores at post-test (Papp et al., 2019). Thus, these conflicting results may be due to the in-person Hatha yoga sessions in the Papp et al., (2019) study being too brief. Further, these sessions occurred once a week compared to two (Chu et al.,

2017) and three (Shohani et al., 2018) times a week, suggesting there may be a specific dose necessary for reducing mental health symptoms.

Other forms of yoga also show positive effects on mental health outcomes (Elstad et al., 2020; Lemay et al., 2019; Maddux et al., 2018; Xu et al., 2021). More specifically, Lemay et al., (2019) and Maddux et al., (2018) showed decreases in stress scores measured by the PSS following a 16-week power yoga (60-minute sessions, 2x/week; Maddux et al., 2019) and 6-week vinyasa yoga and meditation intervention (90-minute sessions, 1x/week; Lemay et al., 2019). Additionally, Elstad et al., (2020) found significant decreases in depression and anxiety scores indicated by the Hopkins Symptom Checklist-25 (HSCL-25) following a 12-week vinyasa yoga intervention (85-minute sessions, 2x/week). And, although not a physical yoga practice, Xu et al., (2021) found a significant effect of a 3-month yoga education intervention (45-minute sessions, 6x/week) on stress levels indicated by Bio-Well scores. Indeed, yoga interventions ranging from 4-12 weeks have shown a significant effect on mental health symptoms, however, there are limitations to consider.

Methodologically the intervention yogic literature lacks a comparison of yoga to an active control and/or typical control (Lemay et al., 2019; Shohani et al., 2018). Other limitations include small sample sizes (Chu et al., 2017; Lemay et al., 2019), lack of internal validity (i.e., different instructors across the intervention; Elstad et al., 2020 and no monitoring of compliance/attendance (Papp et al., 2019), and a lack of physiological measurements to determine potential mechanisms of change (Lemay et al., 2019; Maddux et al., 2018; Papp et al., 2019; Shohani et al., 2018). To this end, additional studies are needed to determine the physiological markers associated with changes in self-report behavioral outcomes. Moreover, there is a need to determine the efficacy of yoga compared to active and/or typical controls on physiological and psychological outcomes.

Section 2.2: Heart Rate Variability

HRV is used as an index of cardiac vagal tone (Laborde et al., 2017) and has been shown to exhibit deficits with symptoms of depression, (Hartmann et al., 2019; Koch et al., 2019), anxiety (Thayer et al., 1996), and stress (Kim et al., 2018). There are a handful of theoretical frameworks that focus on vagal tone and the role of the vagus nerve in multiple regulatory processes (Laborde et al., 2017). The five theoretical models used in past and present research include: 1) Neurovisceral Integration Model, 2) Polyvagal theory, 3) Biological Behavioral Model, 4) Resonance Frequency Model, and 5) Psychophysiological Coherence Model (Laborde et al., 2017). The neurovisceral integration model assumes that there is a connection between the prefrontal cortex (PFC) and the heart via the central autonomic nervous system (ANS) and the vagus nerve (Laborde et al., 2017; Thayer & Lane, 2000). Porges et al., (2001) conceptualized the polyvagal theory, which states that a higher vagal tone indicates optimal regulation of the external and internal environment (Laborde et al., 2017; Porges, 2001). A related model, the biophysiological model assumes that the vagus nerve through vagal tone plays a primary role in the body's energy processes by synchronizing respiration and cardiovascular functions during metabolic and behavioral changes (Grossman & Taylor, 2007; Laborde et al., 2017). Moreover, the resonance frequency model states that breathing at a slow rate at a specified resonance frequency increases vagal tone and positively impacts behavioral outcomes (Laborde et al., 2017; Lehrer & Gevirtz, 2014). Lastly, the psychophysiological coherence model, like the resonance frequency model, posits that slowing individuals' breathing rates can lead to an increase in vagal tone and therefore an increase in effective responses to internal and external stressors (Laborde et al., 2017; Mccraty, 2010). The neurovisceral integration model (Thayer & Lane, 2000) will serve as the framework for the present dissertation as it addresses the physiological underpinnings of the range of behavioral inflexibility seen in individuals experiencing internalizing symptomology (Laborde et al., 2017; Thayer et al., 1996; Thayer & Lane, 2000).

Thayer and Lane (2000) posit that the central autonomic nervous (CAN) system and the anterior executive region (AER) of the brain work complementary to each other in regulating HRV through feedforward and feedback loops. The CAN receives sensory input from the viscera, humor, and environment and coordinates the response to internal and external stressors and changes. While the AER, which has connections to the limbic system and brainstem, plays a role in emotion and activation of the cardiac centers; and has structural overlap with the CAN. The structural organization of the CAN and AER are the foundation of the relationship between HRV and the emotional circuitry (Thayer & Lane, 2000). Therefore, within this theoretical context, HRV can be used as an index of central-peripheral feedback for both physiological and behavioral responses. Specific psychopathologies associated with affect, emotional flexibility, and self-regulation have been linked to dysregulation of HRV (i.e., higher LF/HF and LF and lower RMSSD, SDNN, and HF; Thayer et al., 1996).

Thayer, Friedman, and Borkovec (1996), in their seminal study, evaluated the effects of generalized anxiety disorder (GAD) on vagally mediated HRV; and indeed, those with GAD exhibited a significant reduction in vagally mediate HRV (Thayer et al., 1996). This reduction in vagally mediated HRV was indicated by a decrease in HF power and an increased HR compared to controls without GAD or panic disorder (Thayer et al., 1996). These findings were later supported by a literature review, which not only found the same results across the literature regarding GAD and reduced HRV and PNS input, but also found examples of reduced HRV in individuals with depression in the literature (Cohen et al., 1999). Thayer and Lane (2000) later proposed that deficits in HRV vagal tone mimic cardiac symptomology often exhibited with panic, anxiety, poor attention, ineffective emotional regulation, and behavioral inflexibility (Thayer & Lane, 2000). While there is evidence of HRV deficits in individuals with diagnosed GAD (Cohen et al., 1999; Gorman & Sloan, 2000; Miu et al., 2009) and depression (Cohen et al., 1999; Gorman & Sloan, 2000), there is a need for research to evaluate the HRV markers for individuals with sub-clinical symptoms of depression, anxiety, and stress.

HRV data can be collected using electrocardiogram (ECG) leads or wrist or chest-worn heart rate (HR) monitors (Laborde et al., 2017). The gold standard of HRV measurement is ECG II leads, however, wrist and chest-worn HR monitors are more accessible, cheaper, reliable, and validated (Laborde et al., 2017). To this point, Hernández-Vicente et al., (2021) evaluated the validity of using chest-worn Polar HR Monitors, comparing results with an ECG II lead. The HRV measurements collected from the Polar H7 HR monitor were consistent and there was full agreement at the resting state between the ECG and Polar H7 HR monitor (Hernández-Vicente et al., 2021).

Sampling rates for HRV measurements typically range from 125 to 1000 Hz. However, to obtain a reliable HRV measurement, the suggested sampling rate minimum is 500Hz (Laborde et al., 2017). Measurements of HRV can be short-term (2-3 minutes) or long-term (24 hours) (García et al., 2014; Garcia Martinez et al., 2017; Laborde et al., 2017). One-minute recordings are the minimum and the gold standard is 5 minutes for short-term recordings (Laborde et al., 2017). Additionally, body position can affect the reliability and validity of HRV data collected, thus, the gold standard position is seated, with both feet flat on the ground and hands resting on the thighs. Reliable and valid HRV recordings can provide information on time-domain and frequency-domain variables (Laborde et al., 2017; Rajbhandari Panday & Panday, 2018; Shaffer & Venner, 2013). The time-domain variables include the beat-to-beat intervals (R-R intervals), the standard deviation of all R-R intervals (SDNN), root mean square of successive differences (RMSSD), percentage of successive normal sinus R-R intervals more than 50 ms (pNN50) (García et al., 2014; Laborde et al., 2017; Shaffer & Ginsberg, 2017), and average difference between the highest and lowest heart rates during each respiratory cycle (HRmax-HRmin) (Shaffer & Ginsberg, 2017; Shaffer & Venner, 2013). These variables provide quantification of the variability of inter-beat interval measurements (Shaffer & Ginsberg, 2017). RMSSD particularly provides the most accurate information on vagal tone and is preferred to other time-domain variables (Laborde et al., 2017). The higher the RMSSD, the more vagal tone or input of the PNS, which behaviorally translates to an increased ability to appropriately respond to internal and external stressors (Thayer & Lane, 2000).

Frequency-domain variables obtained through HRV measurements include ultra-low frequencies (ULF) (Laborde et al., 2017; Rajbhandari Panday & Panday, 2018), very low frequency (VLF), low frequency (LF), high frequency (HF), and LF/HF ratio (García et al., 2014; Laborde et al., 2017; Rajbhandari Panday & Panday, 2018; Shaffer & Venner, 2013). These variables provide information estimating the distributions of power, both absolute and relative, into the 4 frequency bands (Shaffer & Ginsberg, 2017). LF/HF more specifically, provides a comprehensive evaluation of sympathetic and parasympathetic input, with HF indicating the amount of vagal tone (Laborde et al., 2017). A lower LF/HF and higher HF are indicative of increased vagal tone and PNS input, which leads to the same behavioral response as an increased measure of RMSSD. Analysis of HRV variables varies depending on which variables are included or being analyzed (i.e., time-domain versus frequency-domain variables)

(García et al., 2014). For the time-domain variables, each analysis will be conducted based on the specific index, however, to conduct these analyses, the RR intervals and HR from a basic ECG need to be identified and filtered (García et al., 2014). Once the appropriate RR intervals have been identified, time-domain-specific analyses can be conducted (e.g., SDNN, RMSSD). To evaluate the frequency-domain variables, an autoregressive (AR), discrete Fourier transformation (DFT), fast Fourier transformation (FFT) (García et al., 2014; Laborde et al., 2017), and a Lomb-Scargle (LS) periodogram is suggested for analysis; however, the LS periodogram is considered the most appropriate analysis (Rajbhandari Panday & Panday, 2018).

There are variables (i.e., stable, and transient) that need to be considered when analyzing HRV (Laborde et al., 2017; Rajbhandari Panday & Panday, 2018; Shaffer & Ginsberg, 2017). Stable variables are those that are not easily controlled but should be controlled at the covariate level; while transient variables can be controlled for (Laborde et al., 2017). Stable variables include age, sex, habitual tobacco use, caffeine, and alcohol consumption, overall health, and medications (Laborde et al., 2017; Rajbhandari Panday & Panday, 2018). Transient variables on the other hand consist of limiting caffeine, tobacco, and alcohol, bathroom use, normal sleep routing, and the level of physical activity before the testing session (Laborde et al., 2017; Rajbhandari Panday & Panday, 2018).

Measurements of HRV have been shown to respond to bouts of exercise and specifically both acute (Albracht-Schulte & Robert-Mccomb, 2018; Nivethitha et al., 2017) and chronic (Chu et al., 2017; Elstad et al., 2020; Hewett et al., 2017; Meshram & Meshram, 2019) bouts and yoga and yogic practices (i.e., yogic breathing). In the current literature, HF has been shown to significantly increase and LF/HF significantly decrease in response to yogic breathing (Nivethitha et al., 2017) and yoga (Chu et al., 2017; Hewett et al., 2019; Meshram & Meshram, 2019); while RMSSD has been shown to exhibit significant (Albracht-Schulte & Robert-Mccomb, 2018; Meshram & Meshram, 2019) and non-significant (Elstad et al., 2020; Nivethitha et al., 2017) increases in response to yogic breathing (Nivethitha et al., 2017) and yoga practice (Albracht-Schulte & Robert-Mccomb, 2018; Elstad et al., 2020; Hewett et al., 2019; Meshram & Meshram, 2019).

Acutely, Nivethetha et al., (2017) evaluated the effects of a 5-minute yogic breathing session on time- and frequency-domain variables of HRV. The study was a single-group repeated-measures study (i.e., pre, during, post) and participants included healthy volunteers from a yoga university (N = 16; M age = 25.30 ± 3.01). There was a significant increase in HF and a decrease in LF/HF after the breathing session, as well as a significant decrease in systolic blood pressure (SBP) and diastolic blood pressure (DBP) (Nivethitha et al., 2017). Additionally, Albracht-Schulte & Robert-McComb (2018) compared the effects of a 90-minute bout of YogaFit (Hatha style yoga flow) compared to a 90-minute quiet sit on both time- and frequency-domain variables of HRV. Participants (N = 40; M age = 20.18 ± 1.97) were randomized to complete the YogaFit or quiet sit session on the first day followed by participation in the opposite condition the next day. Following both acute conditions, participants exhibited a significant main effect of Time for RMSSD and HF in which both measurements of HRV increased after each condition (i.e., 90 minutes of YogaFit and 90 minutes of quiet sitting).

While these acute conditions exhibited a significant effect of yoga and its integral practices (i.e., yogic breathing; (Nivethitha et al., 2017), these studies have limitations. First, Nivethitha et al, (2017) included a small sample size, which calls for more research with a larger sample size. Second, although Albracht-Schulte & Robert-McComb (2018) included a quiet sit condition, it is possible that the yoga condition confounded the results from the quiet sit condition, and vice versa (Albracht-Schulte & Robert-Mccomb, 2018). Thus, neither study included a true control group, nor an active control group. Lastly, there was no comparison of the acute bouts to chronic bouts of yogic breathing (Nivethitha et al., 2017), YogaFit, or quiet sitting (Albracht-Schulte & Robert-Mccomb, 2018). Therefore, it is possible that these results may not be seen in response to chronic exposure. However, chronic bouts of yoga do indeed show the same effects on RMSSD, HF, and LF/HF (Chu et al., 2017; Elstad et al., 2020; Hewett et al., 2017; Meshram & Meshram, 2019). To this end, there is a need for more research evaluating both the acute and chronic effects of yoga and integral yogic practice compared to true controls and/or active controls on HRV variables.

Chu et al. (2017) and Meshram & Meshram (2019) both found significant increases in RMSSD and HF, and significant decreases in LF/HF (Chu et al., 2017; Hewett et al., 2017). Chu et al., (2017) evaluated the effect of a 12-week (60-minute sessions, 2x/week) Hatha yoga intervention on both time- and frequency-domain HRV variables. Participants ($N = 26$) were female volunteers between the ages of 18 and 50 and were randomized into a Hatha yoga (M age $= 33.08 \pm 9.11$) or waitlist control group (M age $= 32.38 \pm 8.27$). After 12 weeks, there was a significant increase in HF and a significant decrease in LF/HF compared to the control group (Chu et al., 2017). Similarly, Meshram & Meshram (2019) conducted a 6-month unspecified yoga intervention (35-minute sessions, 5x/week) to determine the efficacy of chronic yogic practice on time- and frequency-domain HRV variables. The study employed a pre/post-repeated measures design and included 20 participants between the ages of 18 and 20. After the 6-month yoga intervention, participants exhibited a significant increase in HF and RMSSD and a significant decrease in LF/HF (Meshram & Meshram, 2019). Hewett et al., (2017) and Elstad et al., (2020) both employed a randomized control trial in which they evaluated the effects of 16-

week Bikram yoga (45-50-minute sessions, 3-5x/week) and 12-week vinyasa yoga (85-minute session, 2x/week) interventions, respectively, on time- and frequency-domain HRV variables. Both studies found increases in RMSSD (Elstad et al., 2020; Hewett et al., 2017) and HF as well as a decrease in LF/HF (Hewett et al., 2017) in the yoga group compared to the control group, however, these results were not significant.

There are several notable limitations to these findings. Moreover, while Chu et al., (2017) and Meshram & Meshram (2019) found significant results, there are also limitations to consider. The first limitation is the inclusion of a small sample size (Chu et al., 2017; Meshram & Meshram, 2019). Like the acute studies, there is a need to evaluate these interventions with larger sample sizes. Second, there is a lack of internal validity in the Elstad et al., (2020) and Hewett et al., (2017) studies. Elstad et al., (2020) failed to perform fidelity checks across the three yoga instructors in their study, thus leading to a potential instructor bias as well as inconsistencies in the yoga classes. Likewise, Hewett et al., (2017) held their yoga interventions across two Bikram yoga studios, in which participants could choose not only their location of practice but the number of times they attended the yoga sessions a week (i.e., 3, 4, or 5 times a week). Third, and consistent across the yoga literature is the lack of comparisons between acute and long-term yoga interventions (Chu et al., 2017; Elstad et al., 2020; Hewett et al., 2017; Meshram & Meshram, 2019). Lastly, there is a clear need to compare yoga interventions and controls to active control groups to determine the efficacy of yoga over specific integral yogic practices (i.e., yogic breathing, meditation). Taken together, there is a need for research to evaluate the effects of long-term yoga interventions on time- and frequency-domain HRV variables with larger sample sizes with more methodological rigor.

Section 2.3: Electroencephalography

Electroencephalography (EEG) is a visual representation of the electrical activity of populations of cortical pyramidal neurons; and differences in electrical activity of such neurons reflect post-synaptic potentials typically elicited in the lab by presentation of a stimulus during a motor or attention task (Constant & Sabourdin, 2012; Jackson & Bolger, 2014; Olejniczak, 2006; Teplan, 2002). Both wet and dry electrode systems are used in acquiring EEG data. Wet electrodes require the use of conductive gel to facilitate the conduction of ions from cortical neurons to the electrodes (Jackson & Bolger, 2014). The international 10-20 electrode placement system is the most common wet electrode placement (Constant & Sabourdin, 2012; Teplan, 2002), and in this electrode placement system, the names of the electrodes begin with the letter of the brain region that each electrode is measuring (i.e., Frontal, F; Frontopolar, FP; Occipital, O; Central, C; Parietal, P; Temporal, T); and the electrode numbers refer to the hemisphere the electrodes are placed on, with evens representing the right side and odds representing the left. Additionally, the even and odd numerical markings become larger moving from medial to lateral positions (Constant & Sabourdin, 2012; Teplan, 2002).

More recently, portable EEG systems have become popular due to the feasibility of use for various populations, the ease of use, and the ability to collect EEG data during shorter periods (Krigolson et al., 2017, 2021). Unlike traditional EEG systems, portable EEG systems use dry electrodes that are primarily placed across the forehead, are fewer in number, and are applied without conductive gel (Krigolson et al., 2017, 2021). Muse Headsets (Krigolson et al., 2017, 2021), Mind Wave Mobile (Morshad et al., 2020), and Emotiv Epoc Headsets (Melek et al., 2020) are types of portable EEG systems that are feasible for EEG data acquisition. These portable EEG systems have both benefits and costs when it comes to choosing these systems over conventional systems. One benefit is the low cost associated with these systems (Knierim et al., 2021; Morshad et al., 2020; Pu et al., 2021; Simar et al., 2020), with costs ranging from about $100.00 to about $300.00 (Hunkin et al., 2021; Krigolson et al., 2017; Melek et al., 2020). Another benefit is that these systems are much smaller and have fewer electrodes to apply, none of which require conductive gel; making the overall application quick, non-invasive, and less overwhelming (Krigolson et al., 2017; Melek et al., 2020; Morshad et al., 2020; Pu et al., 2021). Unfortunately, there are potential limitations to using these systems. One such limitation is the loss in the number and placement of electrodes. The electrodes are placed in non-standard locations for certain analyses in ERP methodology, thus, depending on the research question it may be unreasonable to use these systems (Krigolson et al., 2021). Another limitation is the potential of noise and artifacts depending on the conditions in which these systems are being used (e.g., motor tasks, exercise) (Pu et al., 2021). Lastly, there is evidence of technical issues such as Bluetooth connectivity failures (Pu et al., 2021). Despite these limitations, the portability, price, and decreased participant discomfort make portable EEG systems appropriate for studies evaluating resting-state EEG in physically or psychologically vulnerable populations.

Visual analysis of raw EEG data acquired from both wet and dry EEG systems reveals sinusoidal waves of different frequencies ranging from 0.5 to 100 hertz (Hz) (Teplan, 2002). EEG band types include alpha, beta, delta, theta, and gamma bands (Constant & Sabourdin, 2012; Jervis et al., 1989; Teplan, 2002). Delta bands are identified with a slow frequency of 0.5 to 4 Hz (Constant & Sabourdin, 2012; Teplan, 2002), and a large amplitude of from 100 to 200 microvolts (Constant & Sabourdin, 2012). Theta bands are identified by a frequency ranging from 4 to 8 Hz (Constant & Sabourdin, 2012; Teplan, 2002), and an amplitude ranging from 50 to 100 microvolts (Constant & Sabourdin, 2012). Increased theta activity is associated with light sleep or sleep stage one, GABAergic activity in the cortico-thalamic neurons (Constant &

Sabourdin, 2012), and cognitive effort (e.g., working memory, spatial navigation, memory encoding, memory retrieval) (Cavanagh & Cohen, 2022). The alpha band is identified by a frequency of 8 to 14 Hz (Constant & Sabourdin, 2012; Jervis et al., 1989; Teplan, 2002) and a high amplitude of 10-20 microvolts (Constant & Sabourdin, 2012)**.** These EEG bands are moderate in speed and have been seen in typically developing individuals with their eyes closed, and during meditation and relaxation (Constant & Sabourdin, 2012). Further, during tasks alpha bands may increase due to active inhibition, which occurs when alpha bands in inactive regions increase to facilitate information processing (Michelmann et al., 2022). The beta band is identified by a frequency of 13 Hz to 30 Hz (Constant & Sabourdin, 2012; Teplan, 2002) and an amplitude of about 30 microvolts (Constant & Sabourdin, 2012). Gamma is the fastest EEG band and is identified by a frequency of 30 Hz and higher (Constant & Sabourdin, 2012; Strüber & Herrmann, 2022; Teplan, 2002).

Currently, there is little research evaluating resting-state EEG measures, specifically alpha and theta band measures, as markers of mental health symptomology. Earlier studies have found that those diagnosed with anxiety, social phobia (Sachs et al., 2004), and obsessive-compulsive disorder (OCD) (Pogarell et al., 2006) exhibited decreased alpha and theta power at rest with their eyes closed when compared to typical controls. Additionally, the higher the anxiety and depression scores were, indicated by the STAI and BDI, the lower the theta and alpha power was (Sachs et al., 2004). Most recently, Moser et al., (2022) provided a comprehensive overview of the role of anxiety on EEG band outcome measures; however, their review focused on event-related EEG measures in individuals with anxiety and specific symptomology (e.g., anxious apprehension, anxious arousal) (Moser et al., 2022). Thus, very little is known about resting EEG (R-EEG) measures and mental health symptomology.

Furthermore, while there is evidence of decreased R-EEG alpha and theta bands in individuals with diagnosed anxiety, social phobia, and OCD; more research is needed to evaluate R-EEG alpha and theta bands as physiological markers of subclinical mental health symptomology.

The current literature evaluating the effects of yoga on EEG bands, specifically alpha and theta bands, is lacking. Few studies have evaluated the effects of acute yoga (Field et al., 2010) and acute yogic practices such as yogic breathing (Bhaskar et al., 2020; Telles et al., 2017) and meditation (Harne & Hiwale, 2018). Specifically, Field et al., (2010) found significant increases in theta band power following a 20-minute session of yoga. Further, following a 30-minute session of Om meditation, theta band power was shown to significantly increase and alpha band power increased; however, this change was not significant (Harne & Hiwale, 2018). Acute sessions of yogic breathing also showed similar effects on alpha and theta band power (Bhaskar et al., 2020; Telles et al., 2017). Bhaskar et al., (2020) found a significant increase in both alpha and theta band power following a 20-minute session of yogic breathing. Comparatively, Telles et al., (2017) found increases in alpha and theta band power following alternative nostril yogic breathing, increases in alpha band power following breath awareness, and increases in theta band power following quiet sitting. However, these changes in alpha and theta band power were not significant.

While acute yoga (Field et al., 2010) and yogic practices (Bhaskar et al., 2020; Harne & Hiwale, 2018) have shown increases in both alpha and theta band power, there are limitations to consider. None of the current studies compare acute yoga and yogic practices to yoga interventions. Further, there is a lack of comparison to true control and/or active control groups (Bhaskar et al., 2020; Field et al., 2010; Harne & Hiwale, 2018), again, a consistent limitation across the yogic literature. Lastly, there has been no research evaluating the effects of long-term bouts of yoga or yogic practices (e.g., yogic breathing, meditation) on EEG band power. Therefore, it is crucial that future research studies not only evaluate the effects of long-term yoga interventions on EEG band power but compare the acute and chronic effects. To this end, there is a need for high-quality research studies to evaluate both acute and long-term effects of yoga, as well as yogic practices, on EEG band power compared to true controls and/or active controls.

In preparation for the present dissertation, an acute randomized crossover study was conducted, which evaluated the effects of a single 45-minute session of Hatha yoga compared to a single 45-minute control session on EEG alpha and theta power and HRV (i.e., LF/HF and RMSSD). 41 healthy young adults, ages 18-40, experiencing and concerned with elevated mental health symptoms participated in the study. Participants were randomized to complete either the 45-minute Hatha yoga session or the 45-minute control session; and following a washout period of 7 days, participants returned to complete the opposite session. Results from a linear mixed effects regression (LMER) showed a main effect of Time, Group, and a Time x Group interaction ($p < 0.01$) for EEG alpha and theta power. The Time x Group interaction was such that following the control condition (45-minutes of sitting quietly ($n = 8$) or video watching ($n = 29$), participants exhibited a significant decrease in both alpha and theta power, reflecting brain activity and cognitive control. Regarding HRV, there was a main effect of Group and a Time x Group interaction ($p < 0.01$), such that following the 45-minute yoga session, LF/HF decreased significantly, indicating increased parasympathetic influence, or behavioral flexibility, decreased stress, and increased inhibitory and cognitive control.

The present yogic literature shows evidence of the effectiveness of yoga on mental health outcomes, both behaviorally and physiologically. However, as mentioned in the review of the literature some limitations must be addressed in determining the effectiveness of yoga on behavioral and physiological measures of mental health. These limitations include small sample sizes, lack of internal and external validity, and methodology that lacks rigor as few studies compare yoga to a control or active control. Moreover, there are no studies evaluating the effects of a long-term yoga intervention on EEG in young adults ages 18-35 with elevated mental health symptoms. Thus, the present dissertation study aims to address these limitations comprehensively with a rigorous study design.

Chapter 3: Methods

Participants

45 participants, ages 18-35 who were experiencing or concerned about depression, anxiety, and stress symptoms were recruited for the present study. These participants were recruited via flyer dissemination through email and throughout the College of Science and Mathematics and the School of Kinesiology. There were both research SONA and monetary incentives for participants in each group. More specifically, participants who were randomized to the yoga and meditation groups received $120.00 and up to 5 SONA credits for completing both the pre-test and post-test and attending at least 15 out of 20 sessions. Participants randomized into the waitlist control group received $50.00 for completing both pre-test and post-test and were offered free yoga classes the following semester. Inclusion criteria included being between the ages of 18 and 35, experiencing some level of depression, anxiety, or stress symptoms as determined by a score of 5 or higher on the Beck Depression Inventory (BDI) and Beck Anxiety Inventory (BAI), and a total score of 7 or higher on the Depression, Anxiety, and Stress Scale-21 (DASS-21). Additionally, participants had to be physically healthy to participate in physical activity as determined by the Physical Activity Readiness Questionnaire for Everyone (PAR-Q+).

Primary Outcome Measures

Beck Depression Inventory (BDI)

The BDI is a 21-item self-report inventory scored 0-3 and assesses clinical characteristics and symptoms of depression such as sadness, self-dislike, fatigue, irritability, unworthiness, and suicidal thoughts (Beck et al., 1961). Scores for each of the items are summed to create a total BDI score which indicates the level of depression. A score of 1-10 indicates normal levels of ups and downs, 11-16 mild mood disturbance, 17-20 borderline clinical depression, 21-30 moderate depression, 31-40 severe depression, and over 40 extreme depression. This inventory shows high reliability (Beck, Steer, et al., 1988; Wang & Gorenstein, 2013), with previous Cronbach's α = .90, and has been validated in college-aged populations (Steer & Clark, 1997) and both clinical and non-clinical populations (Beck, Steer, et al., 1988). Note, the complete BDI can be found in Appendix I. The BDI was given to participants to complete during pre-and post-test. Scores were summed and evaluated in the final statistical analysis. Additionally, the Cronbach's alpha for the BDI for the present study was α = .90 and .91 at pre-test and post-test respectively. Participants with BDI scores above 20 at pre-and/or post-test were provided mental health resources and available treatment options, which can be found in Appendix C.

Beck Anxiety Inventory (BAI)

The BAI is a 21-item self-report inventory assessing clinical characteristics and symptoms of anxiety (Beck, Epstein, et al., 1988). This assessment is reliable (Bardhoshi et al., 2016; Beck, Epstein, et al., 1988; Fydrich et al., 1992) in both clinical and non-clinical populations (Bardhoshi et al., 2016) with previous studies reporting a Cronbach α = .91. Scores for each item range from 0 to 3 and each of the item scores are summed to provide a total BAI score which represents the level of anxiety severity. A total score of 0-21 indicates low anxiety, 22-35 moderate anxiety, and 36 and higher potentially concerning levels of anxiety. Note, the complete BAI can be found in Appendix J. The BAI was given to participants to complete during pre-and post-test. Scores were summed and evaluated in the final statistical analysis and Cronbach's alpha for the BAI for the present study was α = .89 for both pre- and post-test. Participants with BAI scores above 21 at pre-and/or post-test were provided mental health resources and available treatment options.

Depression, Anxiety, and Stress Scale-21 (DASS-21)

The depression, anxiety, and stress scale (DASS-21) is a 21-item questionnaire assessing symptoms of depression, anxiety, and stress (Lovibond, P. & Lovibond, S., 1993). The DASS-21 has been validated in clinical and non-clinical young adults (Coker et al., 2018; Sinclair et al., 2012). Each question is scored 0-3, 0 being did not apply to me at all and 3 being applied to me very much or most of the time. Questions for each subscale are summed to create an overall depression, anxiety, and stress score which indicated the level of symptom severity. A depression score of 0-4 indicates normal symptoms, 5-6 mild depression, 7-10 moderate depression, 11-13 severe depression, and 14 and above extremely severe depression. For anxiety, a score of 0-3 indicated normal symptoms, 4-5 mild anxiety, 6-7 moderate anxiety, 8-9 severe anxiety, and 10 and above extremely severe anxiety. Lastly, a score of 0-7 for stress indicates normal symptoms, 8-9 for mild stress, 10-12 for moderate stress, 13-16 for severe stress, and 17 and above for extremely severe stress. Note, the complete DASS-21 can be found in Appendix K.

For the present study, the DASS-21 was included as an additional mental health measurement as it evaluated internalizing symptoms of depression, anxiety, and stress; three disorders with high subclinical presentation in young adults (American Psychological Association, 2020; Terlizzi & Villarroel, 2019; Villarroel & Terlizzi, 2019). Further, the DASS-21 has been used as a mental health measurement in studies evaluating the effects of yoga on mental health (Hewett et al., 2017; Shohani et al., 2018). The DASS-21 was administered to participants to complete during pre- and post-test. Subscale scores were calculated as well as summed to create a DASS-21 total score for evaluation in the final statistical analysis. Additionally, the Cronbach’s alphas for the DASS-21 subscales for the present study were α = .95 for DASS-21 depression, α = .87 and .88 for DASS-21 anxiety, and α = .89 and .91 for

DASS-21 stress at pre-and post-test. Participants with severe and extremely severe symptoms as indicated by scores of 11 and higher for depression, 8 and higher for anxiety, or 13 and higher for stress, were provided mental health resources and available treatment options. This packet was provided at pre-test but available to participants with severe and extremely severe symptoms throughout the intervention.

Physical Activity Readiness Questionnaire for Everyone (PAR-Q+)

The PAR-Q+ was completed by all participants to determine their physical readiness to participate in physical activity. This questionnaire is a seven-step self-report questionnaire that identifies risk factors, health history, and current symptoms. General health questions included inquiries regarding cardiorespiratory, neurological, and orthopedic function. The complete PAR-Q+ can be found in Appendix E. All participants for the present study were physically healthy to participate in physical activity.

Therapies and Medications Questionnaire

The therapies and medication questionnaire was used to characterize participants' mental health treatments and was a self-report questionnaire given at pre-and post-test. The complete questionnaire can be found in Appendix B. This questionnaire asked the following six questions: 1.) Are you currently seeking treatment for mental health issues related to anxiety, stress, or depressive symptoms? If no, skip to question 4; 2.) If yes, how often do you attend therapy sessions (e.g., 1x/week, 2x/month, etc.); 3.) Who leads your therapy sessions (e.g., counselor, therapist, psychologist, psychiatrist, etc.); 4.) Are you taking any medications related to anxiety, stress, or depression issues? If no, skip to question 5; 5.) Are you taking any herbal supplements related to anxiety, stress, or depression issues? If no, skip to question 6; 6.) Do you feel that the treatment you are receiving has helped to reduce your levels of anxiety, stress, or depressive symptoms?

MUSE-2 EEG Headband and Mind Monitor Application

The MUSE-2 EEG headband (InterAxon Inc.) is a portable and wearable commercial EEG device that collects absolute and relative alpha, beta, gamma, delta, and theta band power from frontal (AF7, AF8) and temporoparietal (TP9, TP10) electrodes. This system also contains a reference, which is located along the center of the forehead (FPz). Further, the MUSE system has been shown concurrently valid for EEG research (Krigolson et al., 2017, 2021), measuring what traditional EEG monitors measures. Mind Monitor (© 2015), developed by James Clutterbuck, is one commercial application that collects and records EEG data from the MUSE system via Bluetooth. EEG data recorded on Mind Monitor is recorded in μV, with a default sampling rate of 512 Hz and default frequency ranges of 1-4 Hz for delta, 4-8 Hz for theta, 7.5-13 Hz for alpha, 13-30 Hz for beta, and 30-44 Hz for gamma. The sampling rate for the MUSE EEG was 256 Hz with a bandwidth from 0.5 to 70 Hz.

For the present study, a 5-minute resting-state EEG was collected before the first Hatha yoga and meditation session and after the last Hatha yoga and meditation session. Resting state EEG was collected for the participants in the control group at the beginning of both pre-and post-test. To collect the resting state EEG, participants sat on a mat with their eyes closed in a dark, quiet room. Each participant was paired with a research assistant who instructed them to remain as still as possible. Raw resting state EEG data was preprocessed, and visually inspected for any artifacts (i.e., facial, and ocular muscle movements and signal loss) and the resting state data was filtered using a bandpass filter of 0.5 to 60 Hz with a minimum-order finite impulse response (FIR) filter and 60 decibel (dB) roll-off. Outlier analysis was run to identify and remove any participants with frontal (AF7, AF8) alpha and theta power values outside of three standard deviations of the mean. A fast Fourier transform with 128 bins and 50% overlap using a Hamming window was run in EEGlab 2023.0. The total spectral power for both frontal electrodes was calculated for the entirety of the EEG data, and average frontal alpha (7.5-13 Hz) and theta (4-8 Hz) power were extracted.

Polar H8/H9 Heart Rate Monitors and HRVLogger

The Polar H8/H9 monitors are commercial chest-worn heart rate monitors that record real-time heart rate data. These monitors have been validated against traditional ECG leads and be valid for HRV research (Hernández-Vicente et al., 2021). HRV Logger is a commercial application that connects to the Polar HR monitors via Bluetooth and extracts, stores, and exports raw beat-to-beat data for HRV data analysis (i.e., time- and frequency-domain variables) as a CSV file. For the present study, a 5-minute resting-state HR was collected before the first and after the last Hatha yoga and meditation sessions. Resting-state HRV data was collected for the participants in the control group at the beginning of both pre-and post-test. Participants sat on a mat with their eyes closed in a dark, quiet room to collect the resting state HR. Each participant was paired with a research assistant who instructed them to remain as still as possible. Raw HRV data in CSV format was then exported to R Studio and filtered (25-200 bpm), interpolated (linear moving window), and RMSSD and LF/HF indices were calculated using the RHRV package.

Secondary Outcome Measures

FITNESSGRAM© Physical Fitness Test

Participants completed physical fitness testing (FITNESSGRAM®) that consisted of resting heart rate and blood pressure, flexibility (sit-and-reach), and muscular strength and endurance (push-ups, curl-ups, grip strength). All the instructions for the physical fitness testing can be found in Appendix D.

Resting Heart Rate and Blood Pressure. The resting heart rate was collected using a finger pulse oximeter (Innovo iP900AP Deluxe, Innovo Medical, Stafford, TX, USA) on the left index finger. Resting blood pressure was measured on the right arm via an Omron automatic blood pressure monitor (5 Series Upper Arm Blood Pressure Monitor BP742N, Omron Healthcare, Inc., Lake Forest, IL, USA).

Shoulder Stretch. The shoulder stretch test measures shoulder flexibility. For the shoulder stretch test of flexibility, participants reached their right hand over the right shoulder and down their back and attempted to bring their left hand to meet their right to touch their fingertips together. Participants then repeated this on their opposite side.

Back Saver Sit and Reach. The sit-and-reach test measures hamstring flexibility. This test was conducted using a sit-and-reach bench, against which participants placed both feet flat. Once their feet were in place and their legs fully extended with no bend in their knees, participants placed one hand on top of the other and slowly pushed the slide on top of the bench as far forward as they could, holding the final distance for at least a second.

Curl-Up Test. The curl-up test measures abdominal strength and endurance. For the curl-up test, participants laid on their backs with their feet flat on the mat and hands touching a line of tape. Participants then curled up until their fingers touched the second line of tape, making sure their heels remained on the floor. They were required to stay on pace with the audio recording of the cadence and were stopped after two incorrect curl-ups.

Push-Up Test. The push-up test measures upper body strength and endurance. For the push-up test, participants started in the “up” position with their hands underneath their shoulders and arms and back kept straight. Female participants had the option to perform the modified push-ups with their knees and tops of their feet against the mat, or a traditional push-up. Participants had to bend their arms until their elbows made a 90-degree angle for the push-up to count, and they completed as many push-ups as they could in a minute.

Body Composition and Anthropometrics

Body composition (i.e., BMI, Body Fat %) was measured using a TANITA total body composition analyzer (SC-331S Total Body Composition Analyzer, TANITA Corporation, Arlington Heights, IL, USA). Additionally, body weight was measured using the TANITA and height using a traditional stadiometer.

Study Procedures

Participants were scheduled to come into the laboratory before the start of the study to complete the PAR-Q, BDI, BAI, and DASS-21. Upon inclusion into the study and signed consent, participants were assigned a randomization number from 1 to 45 and randomized into either the Hatha yoga group, meditation group, or the waitlist control group using the "Pretty Random" random number generator application (Steven Burnett, 2016©). All participants were then scheduled to complete the pre-test therapies and medications questionnaire and physical fitness measurements. Following completion of questionnaires and fitness assessments, participants randomized to the waitlist control group were scheduled to return for EEG and HR data collection while participants in the yoga and meditation intervention sat for the resting-state EEG and HR collection before the start of the first intervention session. Additionally, all enrolled participants received a list of low-cost, confidential, online mental health resources in a packet after completing pre-test. This packet can be seen in Appendix C.

Before the start of the first yoga and meditation session, participants sat on their mats for 5 minutes, and resting state EEG and HR data were collected. This took place in a dark, quiet laboratory space and participants were instructed to keep their eyes closed and remain still. After EEG and HR data collection was completed, participants began their first yoga or meditation session. Both the Hatha yoga and meditation sessions were 45 minutes on Tuesdays and Thursdays from 4-5 PM and 5-6 PM respectively. The intervention took place over 10 weeks. Makeup sessions (3 total) were scheduled into the 10-week interventions to allow for Fall Break (October 7-10) and other potential attendance or session issues. Additionally, attendance was taken before each session.

Following the last session of the Hatha yoga and meditation interventions, a 5-minute resting state EEG and HR data collection was performed. This was completed in the same manner as the pretest with participants sitting at their mat in the dark and quiet laboratory space and instructed to keep their eyes closed and remain still. After EEG and HR data collection, all participants scheduled a time to return to the lab for post-test mental health and physical fitness assessments. For those in the control group and those who did not attend the final yoga or meditation session, resting-state EEG and HR data were collected before participants completed the post-test BDI, BAI, DASS-21, therapies and medications questionnaire, and physical fitness measurements.

Intervention Sessions

Hatha Yoga Sessions

The Hatha yoga sessions were held twice a week on Tuesdays and Thursdays from 4-5 PM in a School of Kinesiology laboratory space. Each session was 45 minutes and consisted of traditional Hatha yoga poses with progressions to more challenging poses and modifications taught by a 200-level registered yoga teacher. Participants in the Hatha yoga group were encouraged to bring their yoga mats, blocks, and straps; however, mats, blocks, and straps were available for all participants. The Hatha yoga poses and session flows are in Table 2 below. Any modifications or progressions to the yoga poses in the session flow were determined by the participants, their progress, and the yoga instructor.

Table 2. *Hatha Yoga Session Flow*

Section and Poses (Pose in Sanskrit)
Integration • Childs Pose (Balasana) • Downward Facing Dog (Adho Mukha Svanasana) • Rag Doll (Uttanasana) • Mountain Pose (Samsthiti)
Awakening • Sun Salutation A (Surya Namaskar) • Sun Salutation B (Surya Namaskar B) • ** Sun Salutations Repeated on Right and Left Sides
Vitality • Crescent Lunge (Ashta Chandrasana) • Warrior II (Virabhadrasana II) • Extended Side Angle (Utthita Parsvakonasana) **Vinyasa to transition to opposite side • Thunderbolt Prayer Twist (Parivrtta Vajrasana) • Garland Pose (Malasana)
Equanimity • Eagle Pose (Garudasana) • Standing Leg Raise (Utthita Eka Padasana) • Dancer Pose (Natarajasana) • Tree Pose (Vrkasana)
Grounding • Triangle Pose (Trikonasana) • Wide Leg Forward Fold (Prasarita Padottanasana) • Pyramid Pose (Parsvottanasana) • Twisting Triangle (Parivrtta Trikonasana) **Vinyasa to transition to opposite side
Igniting • Locust Post (Salabhasana) x2 • Floor Bow (Dhanurasana) x2 • Bridge Pose (Setu Bandha Sarvangasana) x2 • Dead Bug (Ananda Balasana)

Opening • Half Pigeon Pose (Ardha Kapotasana)
Release • Seated Single Leg Extension (Janu Shirasana) • Seated Forward Fold (Paschimottanasana)
Deep Rest • Supine Twist (Supta Matsyendrasana) • Reclining Bound Angle Pose (Suptha Baddha Konasana) • Corpse Pose (Savasana)

Meditation Sessions

The meditation sessions were held twice a week on Tuesdays and Thursdays from 5-6 PM in the same laboratory space as the Hatha yoga sessions. Each session was 45 minutes and consisted of introductions to each yogic limb, guided breathing exercises, and guided meditation. Participants in the meditation group were encouraged to bring their yoga mats, blankets, and bolsters; however, mats, blankets, and bolsters were available for all participants. Across the 20 sessions, the instructor introduced all 8 limbs of the yogic path and individual aspects of each limb. The first two sessions began with a letter-writing exercise in which participants were instructed to write a letter to themselves that they reflected upon following the 10-week intervention. Each session included breathing exercises (e.g., alternative nostril breathing, 3-part breathing, ujjayi breathing, mudra breathing, box breathing, and color breathing) and visualization meditation exercises (e.g., compassion, progressive muscle relaxation, imagery). Additionally, the instructor ended each session with an introduction to the session topic and asked thoughtful questions for each participant to reflect on in the context of their lives. The sessions and the associated session topics and questions for participants are in Table 3 below. The instructor made scripts and takeaway handouts for each session which can be found in Appendices F and G respectively.

Table 3. *Meditation Session Topics and Session Questions*

Session(s)	Session Topic (Session Topic in Sanskrit)	Session Primary Questions
Restraints, Moral Disciplines, or Ethics (The Yamas); Sessions 1-8		
Sessions 1 and 2	Restrain, Control, or Contain (Yama)	1. What boundaries do you place in your mind and body to maintain control? 2. What boundaries are in your life to help maintain control? 3. What limits do you put in your relationships that help you maintain control? 4. What boundaries do you place in your routine to maintain ease and control? 5. How can you apply yama into your daily life?
Sessions 3 and 4	Non-Violence (Ahimsa)	1. How can we create a safe space in our minds and bodies? 2. What practices do you have at home and in public to create a safe space? 3. How can you apply ahimsa into your daily life?
Session 4	Truthfulness (Satya)	1. Do you consider yourself an honest person? 2. Are we always aware when or why we are lying? 3. How can you apply satya into your daily life?
Session 6	Non-Stealing (Asteya)	1. Is there anything you could have done to bring more joy into the moment? 2. Do you feel yourself buying things you don't need? 3. Do you underestimate your own talent? 4. Do you remember to go into the dark places you fear of treading the most? 5. How can you apply asteya into your daily life?
Sessions 7 and 8	Right Use of Energy (Brahmacharya)	1. Where is your energy most directed? 2. Do some people drag your energy down? Do others make you light up? 3. Is there something you love doing that really gives you a boost? 4. Do you find yourself assigning small identities to yourself such as "I am this", "I am small", "I am a good person", "I am a bad person", "I am hopeless"? 5. How can you apply brahmacharya into your daily life?
Positive Duties or Observances (The Niyamas); Session 9-13		
Session 9	Cleanliness (Saucha)	1. Do you act with purpose or out of reactivity? 2. Do you have clean and pure thoughts that reinforce positivity? Or do you consistently have protruding thoughts that dirty up your mind? 3. What are some impurities in your life that may be distracting?

		4. What kind of impure thoughts do you have that may be distracting you; and what are some opposite thoughts you can begin to cultivate? 5. What are some habits that could benefit from saucha? How can I break these habits? 6. What are the common patterns in my home, workplace, care, etc., that can be improved upon? 7. What repetitive thought patterns do I have about myself or others that may be negative or impure? How can I incorporate cleanliness in my thought patterns so that I may "flip it" and include positive, healthy thoughts? 8. How can you apply saucha into your daily life?
Session 10	Contentment (Santosha)	1. Are you content? 2. What keeps you from feeling content or satisfied? 3. Do you start your day in a state of disappointment or in a state of fulfillment? 4. How often does your consciousness automatically lean toward the negative? 5. How often do you appreciate your health, economic well-being, the love you have received, freedom and security? 6. Where is your focal point or Drishti? What do you find yourself focusing on? 7. How often does the phrase, "I'll be happy when…." crosses your mind? 8. How can you apply santosha into your daily life?
Session 11	Discipline or Burning Desire (Tapas)	1. In this moment what do you need? 2. Who in tour life would you describe as courageous? What struggles did she/he/they face? How did she/he/they overcome these struggles? 3. What is your greatest fear right now? Why is that coming up for you? What would it be like to see this fear through the frame of love or compassion? 4. What would be nourishing to you in your life right now? What about long-term? Have you been denying any parts of yourself? If so, why? 5. How can you apply tapas into your daily life?
Session 12	Self-Study or Self-Reflection (Svadhyaya)	1. Our breath is a good indicator of what our self is feeling. If you notice your breath resembles, first ask yourself why. Is there a reason to be stressed or worried? Does it matter right now? 2. Where do you hold tension? Why is this tension present and how often does it arise? 3. What thoughts are filling your head?

		4. What are you specifically made of? What are well all made up of and what do we all have in common? 5. How can you apply svadhyaya in your daily life?
Session 13	Surrender to a Higher Power (Ishvarapranidaha)	1. Do you view your surrender as negative? If so, why? 2. What can you surrender in order to feel less stressed or less weighed down? 3. Do you have trouble relinquishing control in your life? 4. Are you fairly easy-going? Do you allow life to happen without too much of your own force? 5. When you've put in a lot of effort into something that's important to you, do you often worry about what might happen as a result, such as "Will they like me?", "What if I am not good enough?", or "Will this be successful?"? 6. Are you an easily trusting person or do you keep yourself from opportunities due to fear or mistrust? 7. How can you apply ishvarapranidaha into your daily life?
Yoga Poses and On Mat Practices (Asana); Sessions 14-16		
Session 14	Postures or Being Present in One's Body (Asana)	1. How do you balance strength and ease in your life? 2. Do you find an overabundance of strength in some areas and lightness in others? 3. When you're working out or being active, are you aware of your body and what you're doing? Or are you just going through the motions? 4. Are you actively keeping a mind-body connection? Or does your body act without thinking or think without acting? 5. How can you apply asana into your daily life?
Session 15	Stability, Intent, and Strength (Sthika)	1. Where in your life do you feel stable? 2. Where in your life do you feel stable? 3. Do you keep a well-paced routine, or do you feel rushed at certain times when you could be taking your time? 4. Do you feel grounded, or do you feel loosely connected like you could slip away or fall at any moment? 5. How can you apply sthira into your daily life?
Session 16	Comfort, Ease, and Openness, or Good Space (Sukham)	1. What was the last time you felt fully at ease? 2. Do you have a balance of ease and strength in your life? Where do you need more ease?

		3. Why is it hard for you to be relaxed? Is there something or someone that keeps you from feeling this way? 4. How can you apply sukham into your daily life?
Breathing Techniques (Pranayama); Session 17-18		
Sessions 17 and 18	Breathing Techniques Pranayama	1. What kind of breathing pattern do you have? 2. How does your breathing affect your mood? 3. How often do you take the time to consciously breathe? 4. How does your routine affect your breath? How does the time of day affect your breath? 5. Do you find your natural breath to be ragged or deep? Through your nose or your mouth? 6. How can you apply pranayama into your daily life?
Withdrawal of Sense and Meditative Techniques; Sessions 19-20		
Session 19	Sense Withdrawal (Pratyahara)	1. When you are in a state of peace or silence, how often do you get distracted or can't let go of the impulses and distractions of the outside world? 2. Is it difficult for you to find savasana or a deep rest? Why? 3. Do you find that you withdraw or escape for boring or difficult situations? 4. How can you withdraw to your thoughts and be in a state of non-reaction without completely leaving the world around you? 5. How do you balance reactions with physical stimuli? Impressions from the five senses? Associations with others? 6. How to apply pratyahara into your daily life?
Session 20	Focused Concentration, Meditative Absorption, and Bliss or Enlightenment (Dharana, Dyana, and Samahdi)	1. Sitting in silence, what crosses your mind? Are you now sitting with a relaxed or tense physical body? 2. How hard is it for you to concentrate? Or rather, concentrate on just one thing? 3. What do you find yourself concentrating on when you're not actively moving-someone? something? school? work? 4. Is what you concentrate on contributing to positive growth and awareness? Or is it hindering your ability to move forward? 5. What are things you can concentrate or meditate on that will allow you to stay content in a state of stillness and quiet? What will keep you from feeling a need to escape and leave your internal mind?

Waitlist-Control

All the participants randomized to the control group were instructed to continue their usual routine over 10 weeks. After completing the post-test measurements, participants in the control group were offered free 45-minute Hatha yoga classes two times a week for 10 weeks during the Spring 2023 semester. The sessions were offered by the same yoga teacher and included the same Hatha flow, which can be seen in Table 3.

Statistical Approaches

Raw EEG data were preprocessed, transformed using a fast Fourier transform, and log-transformed average frontal alpha and theta power (i.e., averaged across AF7 and AF8) were calculated using MATLAB (R2022a) statistical software and the EEGlab 2023.0 statistical package. The raw HR data was interpolated, filtered, and analyzed in RStudio (Version 1.4.1106) using the statistical package RHRV (Hernández-Vicente et al., 2021), and individual LF/HF and RMSSD values were calculated for each participant. HRV data was then saved and imported to MATLAB for the final analysis. A repeated-measures analysis of variance (rm-ANOVA) with a between- (Group: Control, Meditation, Yoga) and within-subjects factor (Time: Pre-test, post-test) was conducted to evaluate the difference in EEG frontal alpha and theta power, LF/HF, and RMSSD values, and BDI, BAI, and DASS-21 scores over time. A secondary rm-ANOVA with the same between- and within-subjects factors was conducted to evaluate changes in physical fitness measurements.

To conduct a rm-ANOVA with a between and within-subjects factor the following assumption must be met: 1. Independence, 2. Normality, and 3. Sphericity. Thus, before analysis, the rm-ANOVAs, a test of assumptions was conducted for each statistical model. Independence was met as the study observations in each group were independently obtained. However, normality was tested using a Shapiro-Wilk normality test and sphericity was tested using Mauchly's Sphericity test. Additionally, any significant models that did not satisfy our sphericity assumption were corrected using a Greenhouse-Geiser correction. The report for the assumption testing for each statistical model can be seen in Appendix H. Final analyses were conducted in MATLAB (R2022b) and the significance level was set at 0.05.

To address Aim 1, a rm-ANOVA with a between- and within-subjects factor was conducted to assess changes in BDI, BAI, and DASS-21 depression, anxiety, stress, and total mean scores from pre-test to post-test. Time (i.e., pre and post) was the within-subjects factor and Group (i.e., control, meditation, and yoga) was the between-subjects factor.

H1: The 10-week Hatha yoga intervention will lead to significant reductions in depression, anxiety, and stress as measured by the BDI, BAI, and DASS-21. Depression, anxiety, and stress symptoms will be significantly lower following the Hatha yoga and meditation intervention compared to the control.

The following models will address hypothesis 1:

BDIPost-BDPre~Group x Time

BAIPost-BAIPre~Group x Time

DASSDepPost-DASSDepPre~Group x Time

DASSAnxPost-DASSAnxPre~Group x Time

DASSStressPost-DASSStressPre~Group x Time

DASSTotalPost-DASSTotalPre~Group x Time

To address Aim 2, a rm-ANOVA with a between- and within-subjects factor was conducted to assess changes in inhibitory brain activity and cognitive control as indicated by increased frontal alpha and theta band power, respectively, from pre-test to post-test. Time (i.e., pre and post) was the within-subjects factor and Group (i.e., control, meditation, and yoga) was the between-subjects factor.

H2: The 10-week Hatha yoga intervention will lead to significant increases in in inhibitory brain activity and cognitive control as measured by increased frontal alpha and theta band power, respectively. The Hatha yoga and meditation groups will exhibit significantly higher cognitive and inhibitory control as measured by increased frontal alpha and theta band power compared to the control group after the 10 weeks.

The following models will address hypothesis 2:

AlphaMeanPost-AlphaMeanPre x Time

ThetaMeanPost-ThetaMeanPre~Group x Time

To address Aim 3, a rm-ANOVA with a between- and within-subjects factor was conducted to assess changes in behavioral flexibility and increased vagal tone indicated by decreases in LF/HF and increases in RMSSD mean scores from pre-test to post-test. Time (i.e., pre and post) was the within-subjects factor and Group (i.e., control, meditation, and yoga) was the between-subjects factor.

H3: The 10-week Hatha yoga intervention will lead to parasympathetic dominance and behavioral flexibility as measured by a significant increase in RMSSD and a significant decrease in LF/HF. The Hatha yoga and meditation groups will exhibit parasympathetic dominance and behavioral flexibility as measured by a significantly higher RMSSD and lower LF/HF compared to the control group.

The following models will address hypothesis 3:

LFHFMeanPost-LFHFMeanPre~Group x Time

RMSSDMeanPost-RMSSDMeanPre~Group x Time

Chapter 4: Results

Participant Demographics

Figure 1 depicts the consort diagram for the present study. A total of 45 participants were recruited to participate in the study. One participant dropped out of the study and did not attend pre-test. Complete pre-and post-test data were collected for 39 participants. The participants ranged in age from 18-30 years with a mean age of 21.16 years (± 2.7 years) for all participants. The Therapies and Medications Questionnaire revealed that 26/44 participants were receiving mental health treatment (i.e., therapy, medications, or both therapy and medication) at the beginning of the study. Specifically, 16 participants were taking medication, 10 participants were attending therapy sessions, and five of the 26 participants were receiving both therapy and taking medications. Twelve participants found that the mental health treatment they received was effective, nine did not find their mental health treatment effective, and five did not respond. Medications taken across participants included supplements and/or vitamins and minerals (n = 7), selective serotonin reuptake inhibitors (SSRIs, n = 4), a combination of types of medication (n = 2), anxiolytics (n = 2), and stimulants (n = 1). Participant attendance for the meditation intervention ranged from 12 to 18 out of 20 sessions. For the yoga intervention, attendance ranged from 11 to 17 out of 20 sessions. The average attendance for the meditation and yoga groups was 15.1 and 13.9 sessions out of 20 respectively. Table 4 (below) shows the group demographics, specifically age, mental health treatment information at pre-test, and overall participant attendance.

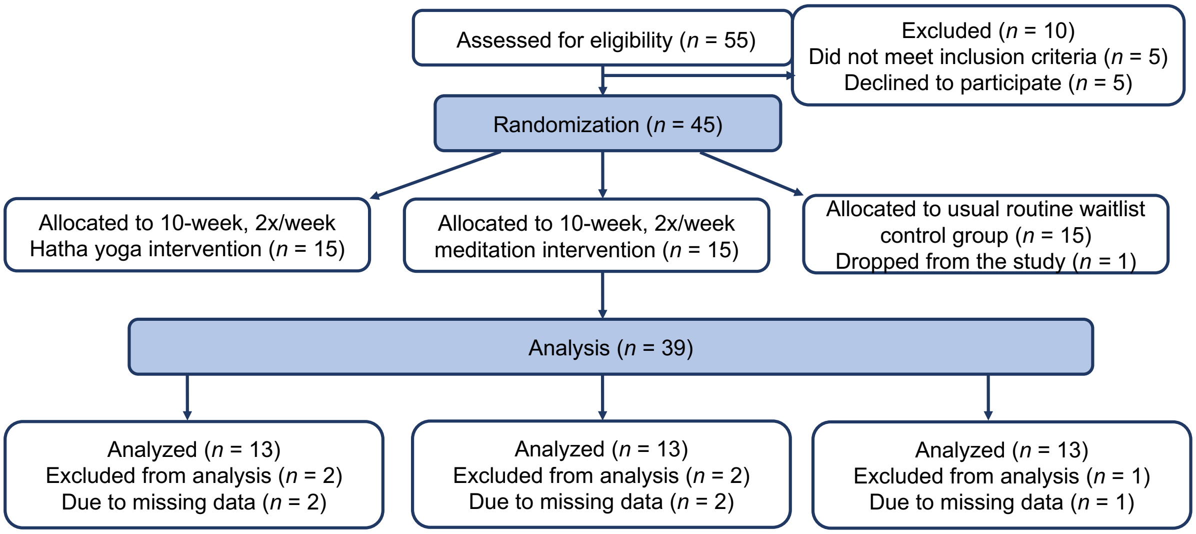

Figure 1. *Randomized Control Study Flow Diagram*

Table 4. *Group Demographics at Pre-Test*

Group	Mean Age in Years (*SD*)	Session Attendance (*SD*)	Therapy (% of sample)	Medications	Therapy & Medications (% of sample)
Control (n = 14)	21.21 (± *3.35*)		4 (28.6%)	SSRIs = 2 SVM = 2 Anxiolytics = 1 Combination = 1	2 (14.3%)
Meditation (n = 15)	21.36 (± *2.76*)	15.1 (± *1.96*)	4 (26.7%)	SSRIs = 2 SVM = 2 Stims = 1	2 (13.3%)
Yoga (n = 15)	20.9 (± *2.11*)	13.9 (± *2.25*)	2 (13.3%)	SVM = 3 Anxiolytics = 1 Combination = 1	1 (6.7%)

Note: Age (in years); Session Attendance, Average session attendance out of 20 possible sessions; Therapy, Receiving therapy from counselor or therapist; Medications, Taking one or more medication; Therapy and Medications, Receiving therapy and taking one or more medications; SSRIs, Selective Serotonin Reuptake Inhibitors; SVM, Supplements/Vitamins/Minerals; Combination, Combination of multiple types of medication; Stims, Stimulants; Receiving therapy and taking medication

Primary Outcomes Measures

BAI Scores

Table 5 shows the number of study participants in each group who were categorized as minimal, mild, moderate, and severe based on their symptom severity scores on the BAI and BDI. The rm-ANOVA evaluating the effect of Time and Group on BAI score did not reveal a significant or a Group x Time interaction ($F(2,36) = 1.72$, $p = .193$), nor a significant main effect of Group ($F(2,36) = .81$, $p = .45$); but did reveal a significant main effect of Time ($F(1,36) = 4.88$, $p = .034$). The main effect of Time was such that there were lower BAI scores across all groups at post-test than pre-test.

BDI Scores

The rm-ANOVA evaluating the effect of Time and Group on BDI score revealed a significant Group x Time interaction ($F(2,36) = 5.99$, $p = .006$) and a significant main effect of Time ($F(1,36) = 4.78$, $p = .035$); but not a significant effect of Group ($F(2,36) = .20$, $p = .82$). The results are such that the meditation and yoga groups exhibited a decrease in BDI scores over time while the control group exhibited an increase in BDI scores over time. A Tukey’s post-hoc test revealed that the meditation group exhibited a significant decrease in BDI scores over time ($p < .001$).

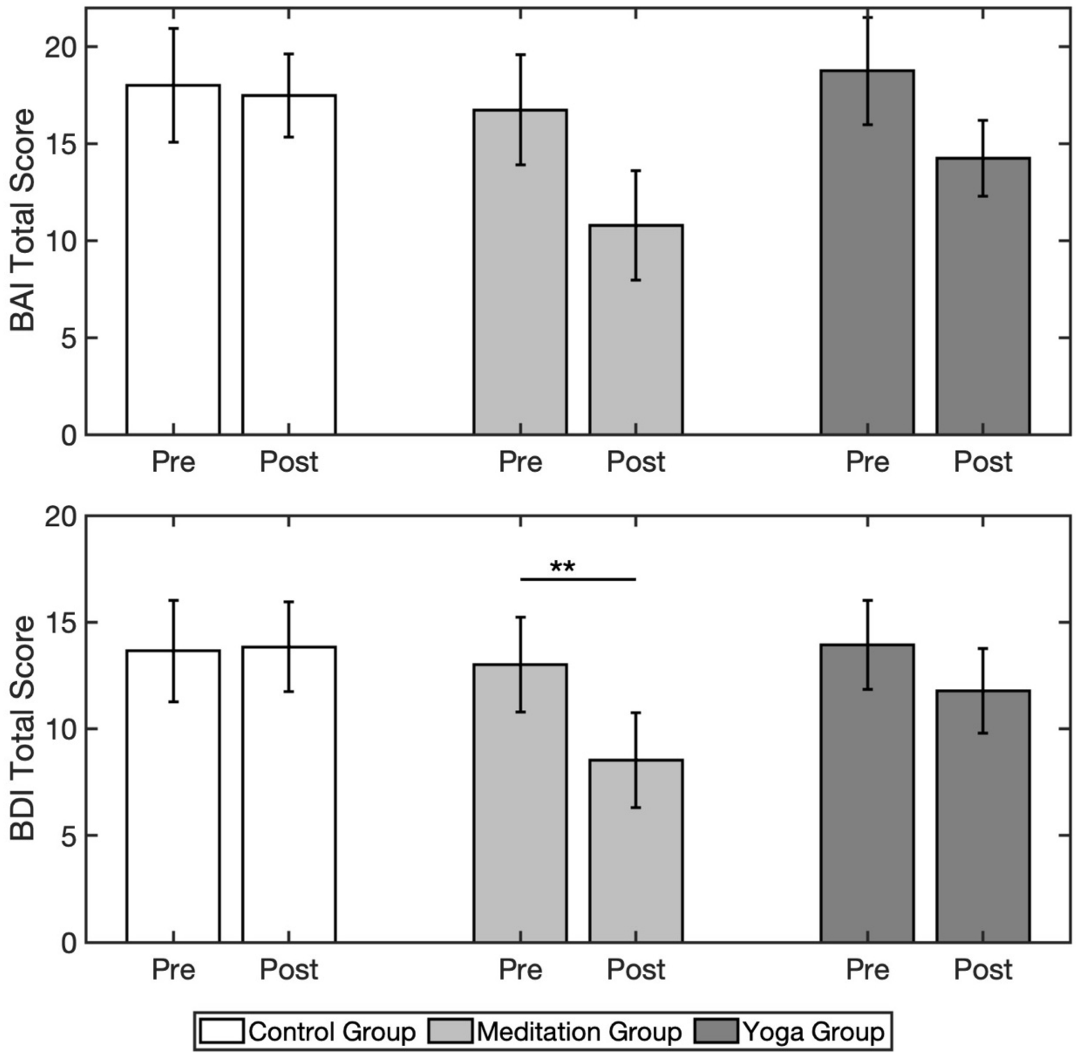

Figure 2. *Changes in Beck Anxiety and Depression Inventory Scores from Pre- to Post-Test.* The group means are represented by each bar, pre and post, with standard error shown. Level of significance represents a significant Group x Time interaction; *** $p < 0.001$.

Table 5. *Number Of Participants in Pre- and Post-Test Categories of BAI and BDI Symptom Severity*

Symptom Severity Category	Group	BAI Pre	BAI Post	BDI Pre	BDI Post
Minimal	Control	4	3	6	5
	Meditation	3	4	8	7

	Yoga	2	3	8	8
Mild	Control	5	4	3	3
	Meditation	3	6	4	5
	Yoga	6	6	3	4
Moderate	Control	2	5	3	4
	Meditation	5	2	3	1
	Yoga	4	4	1	1
Severe	Control	4	1	3	1
	Meditation	4	1	0	0
	Yoga	3	0	2	0
Note: BAI, Beck's Anxiety Inventory; BDI, Beck's Depression Inventory; Severity Categories, Minimal = 0-7, Mild = 10-16, Moderate = 17-29, Severe = 30-63					

DASS-21 scores

DASS Anxiety. The rm-ANOVA did not reveal a significant Group x Time interaction ($F(2,36) = .99$, $p = .38$), nor a significant main effect of Time ($F(1,36) = 3.82$, $p = .06$), or Group ($F(2,36) = .14$, $p = .87$).

DASS Depression. The rm-ANOVA revealed a significant Group x Time interaction ($F(2,36) = 4.72$, $p = .012$), but not a main effect of Time ($F(1,36) = 1.65$, $p = .21$) or Group ($F(2,36) = .28$, $p = .76$). More specifically, Tukey's post-hoc test revealed that the meditation group exhibited a significant decrease from pre-test to post-test ($p = .012$).

DASS Stress. The rm-ANOVA evaluating the effect of Time and Group on the DASS Stress score revealed a significant Group x Time interaction ($F(2,36) = 4.93$, $p = .013$) and a significant main effect of Time ($F(1,36) = 17.78$, $p < .001$); but did not reveal a significant main effect of Group ($F(2,36) = .19$, $p = .83$). These results were such that both the meditation ($p < .001$) and yoga ($p < .01$) groups exhibited significant decreases in DASS-21 stress scores, as shown by Tukey's post-hoc test.

DASS Total Score. The rm-ANOVA revealed a significant Group x Time interaction ($F(2,36) = 6.40$, $p = .004$) and main effect of Time ($F(1,36) = 4.51$, $p = .04$); but not a significant main effect of Group ($F(2,36) = .53$, $p = .59$). A Tukey's post-hoc test revealed that the meditation group exhibited a significant decrease in DASS-21 total score from pre-test to post-test. The yoga group also exhibited a decrease over time from pre- to post-test; however this change failed to reach significance ($p = .06$). Further, the control group showed a non-significant increase in DASS total score from pre-test to post-test.

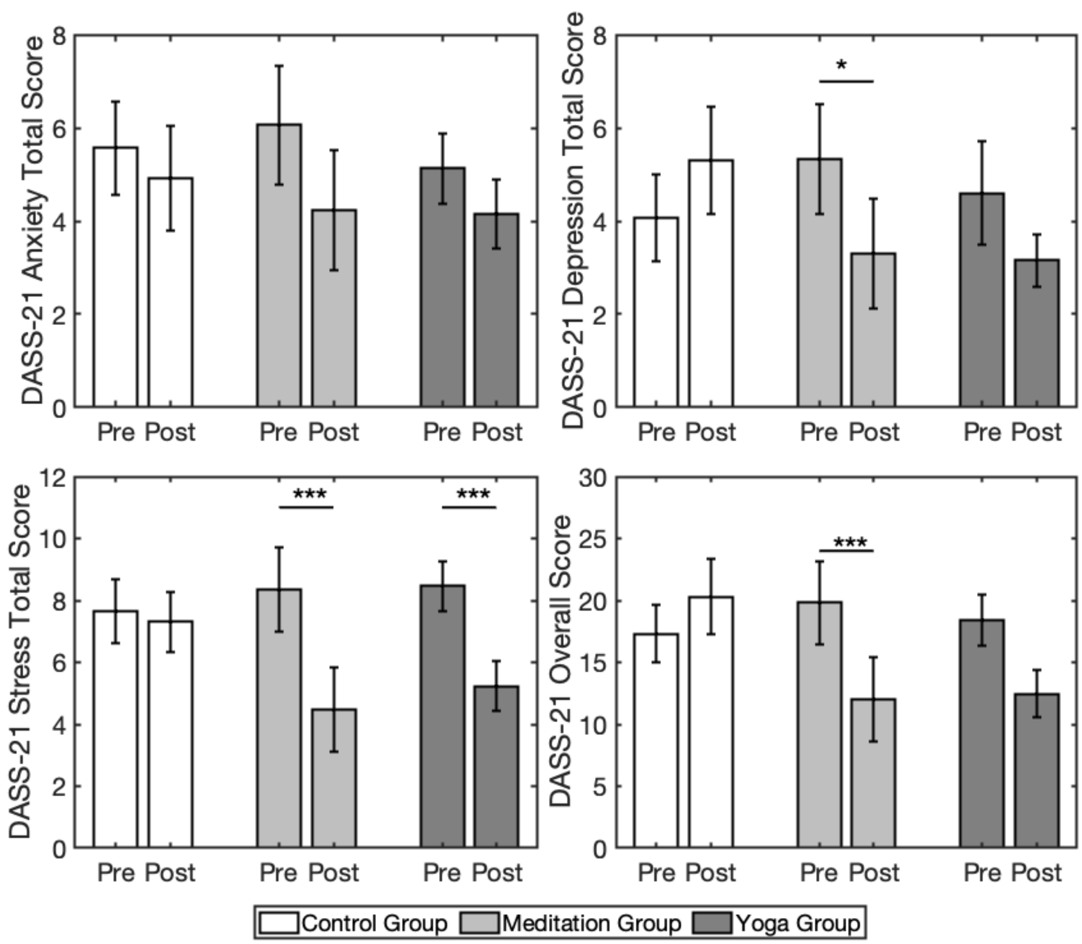

Figure 3. *Changes in DASS-21 Anxiety, Depression, Stress, and Overall Scores from Pre- to Post-Test.* The group means are represented by each bar, pre and post, with standard error shown. Level of significance represents a significant Group x Time interaction; * $p < .05$, *** $p < .001$.

Table 6. *Pre- and Post-Test Mental Health Statistics*

Mental Health Outcome Measure	Group	Pre-Test Mean (*sd*)	Post-Test Mean (*sd*)	F-Statistic	DF	P-Value	Effect Size
BAI	Control	18 (± *11*)	17.5 (± *8*)	1.7	2,36	$p = .19$	$\eta^2 = .08$
	Meditation	16.7 (± *11*)	10.8 (± *10.6*)				
	Yoga	18.7 (± *10.7*)	14.2 (± *7.6*)				
BDI	Control	13.6 (± *8.9*)	13.9 (± *7.9*)	6.0	2,36	$p < .001$	$\eta^2 = .30$
	Meditation	13 (± *8.6*)	8.5 (± *6*)				
	Yoga	13.9 (± *8.1*)	11.8 (± *7.7*)				
DASS-21 Anxiety	Control	5.6 (± *3.7*)	4.9 (± *4.2*)	1.0	2,36	$p = .38$	$\eta^2 = .05$
	Meditation	6.1 (± *5*)	4.2 (± *4.4*)				
	Yoga	5.1 (± *2.9*)	4.2 (± *2.9*)				
DASS-21 Depression	Control	4.1 (± *3.5*)	5.3 (± *4.3*)	4.7	2,36	$p = .01$	$\eta^2 = .25$
	Meditation	5.3 (± *4.6*)	3.3 (± *2.9*)				
	Yoga	4.6 (± *4.3*)	3.2 (± *2.2*)				
DASS-21 Stress	Control	7.6 (± *3.8*)	7.3 (± *3.6*)	4.9	2,36	$p = .01$	$\eta^2 = .18$
	Meditation	8.3 (± *5.3*)	4.5 (± *4.1*)				
	Yoga	8.5 (± *3.1*)	5.2 (± *3.1*)				
DASS-21 Overall	Control	17.3 (± *8.7*)	20.3 (± *11.4*)	6.4	2,36	$p = .004$	$\eta^2 = .32$
	Meditation	19.8 (± *13.1*)	12 (± *9.1*)				
	Yoga	Y: 18.4 (± *8.1*)	12.5 (± *7.4*)				

Note: BAI, BDI, DASS-21 Anxiety, DASS-21 Depression, DASS-21 Stress, DASS-21 Overall; Pre-Test Means, Post-Test Means; F-Statistic from rm-ANOVA; DF, Degrees of Freedom; P-value, Value of significance; Effect size represented by eta squared (η^2)
**** F-Statistic, DF, P-Value, and Effect size are provided for the Group x Time Interactions; Bolded values represent a significant Group x Time Interaction**

EEG Spectral Power

Frontal Alpha Power. The rm-ANOVA evaluating the effect of Time and Group on average frontal alpha power did not reveal a significant Group x Time interaction ($F(2,26) = .67$, $p = .53$) or a significant main effect of Group ($F(2,26) = .58$, $p = .57$); but did reveal a significant main effect of Time ($F(1,26) = 66.49$, $p < .001$). Participants exhibited a decrease in alpha power from pre-test to post-test, regardless of group, indicating a decrease in inhibitory brain activity and cognitive control.

Frontal Theta Power. The rm-ANOVA evaluating the effect of Time and Group on average frontal theta power did not reveal a significant Group x Time interaction ($F(2,26) = .65$, $p = .53$) or a significant main effect of Group ($F(2,26) = .02$, $p = .98$); but did reveal a significant main effect of Time ($F(1,26) = 14.04$, $p < .001$). Participants exhibited a decrease in theta power from pre-test to post-test, regardless of group, indicating a decrease in cognitive control.

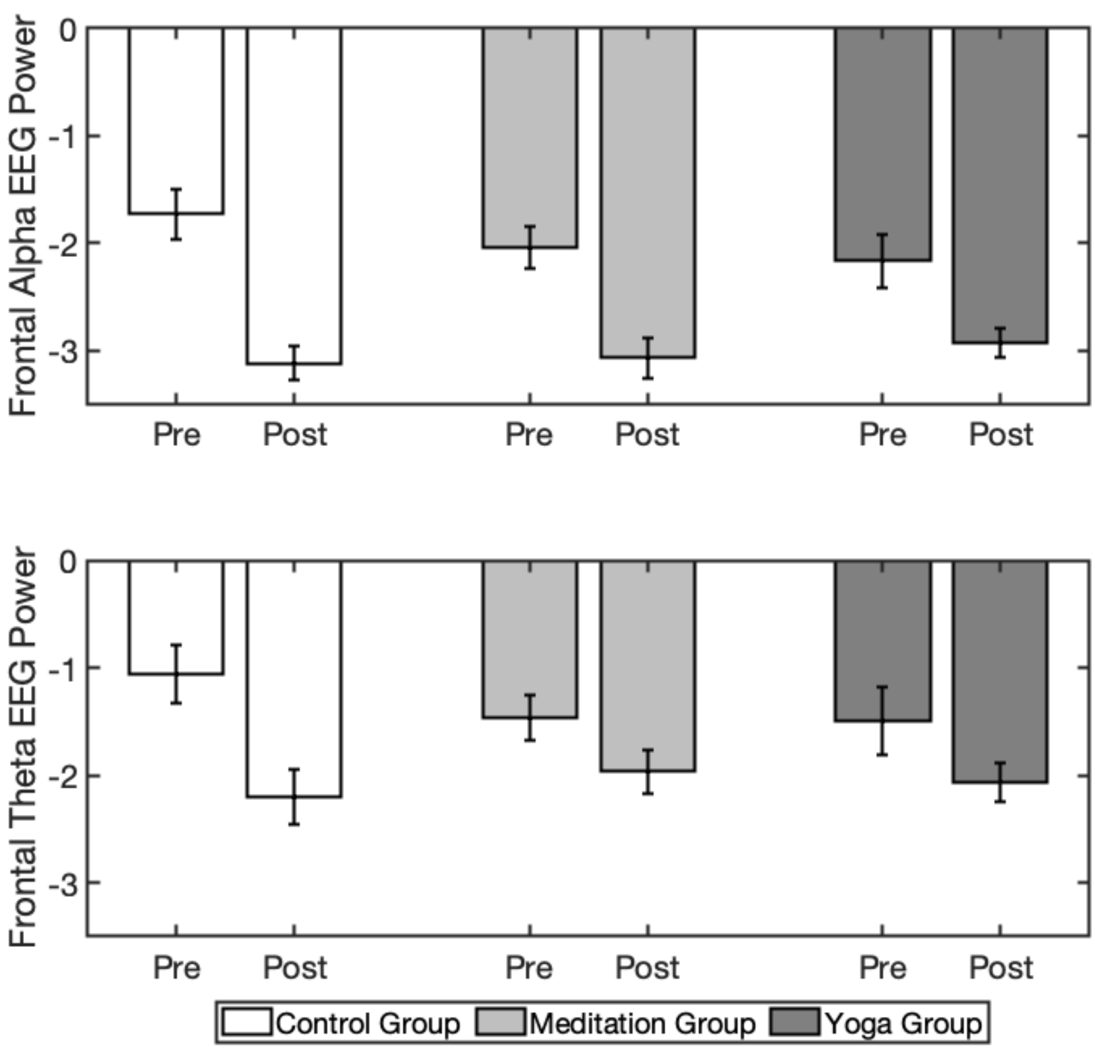

Figure 4. *Changes In Frontal Alpha and Theta EEG Power from Pre- to Post-Test.* The group means are represented by each bar, pre and post, with standard error shown.

Heart Rate Variability

RMSSD. The rm-ANOVA evaluating the effect of Time and Group on RMSSD did not reveal a significant Group x Time interaction ($F(2,34) = .27$, $p = .77$), main effect of Time ($F(1,34) = .51$, $p = .48$), or main effect of Group ($F(2,34) = .22$, $p = .81$).

LFHF. The rm-ANOVA evaluating the effect of Time and Group on LFHF did not reveal a significant Group x Time interaction ($F(2,34) = 1.26$, $p = .29$), main effect of Time ($F(1,34) = .01$, $p = .91$), or main effect of Group ($F(2,34) = .23$, $p = .79$).

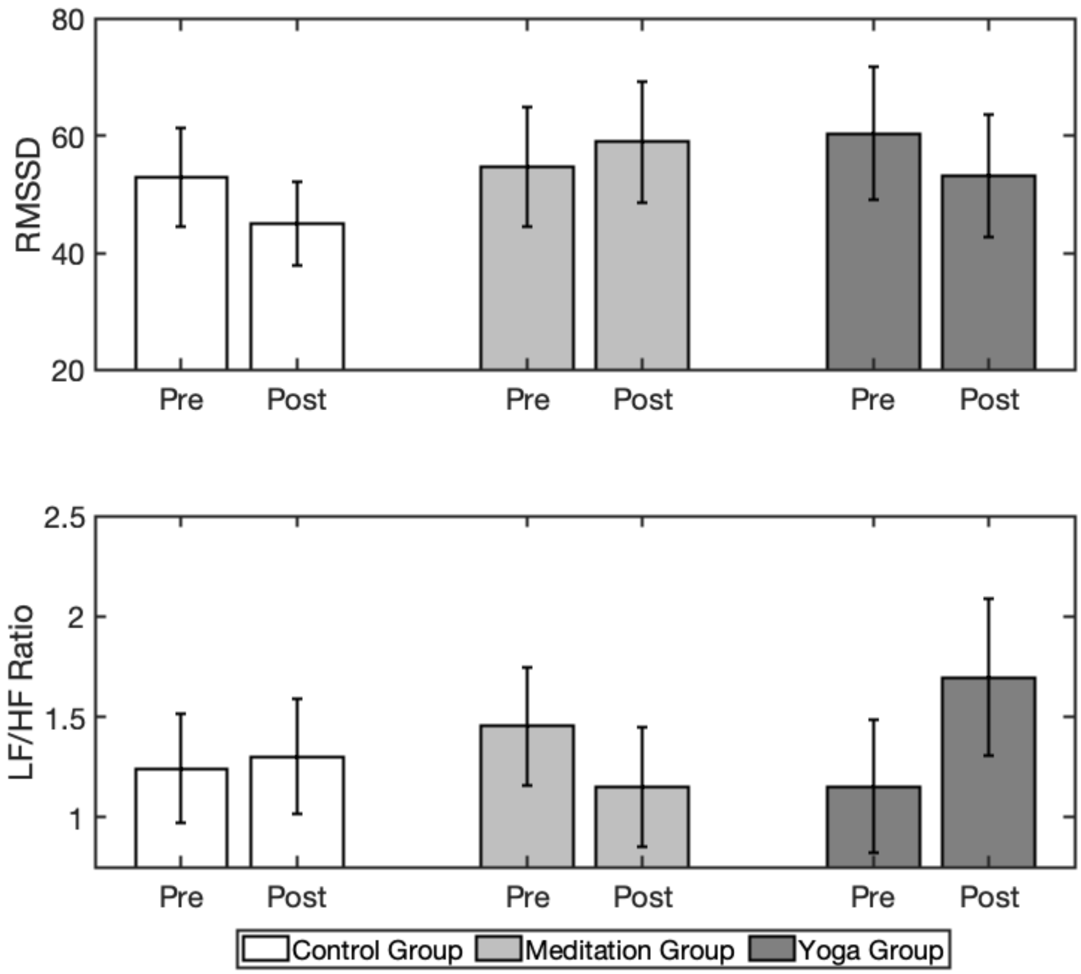

Figure 5. *Changes in RMSSD and LFHF Indices from Pre- to Post-Test.* The group means are represented by each bar, pre and post, with standard error shown.

Table 7. *Pre- and Post-Test Physiological Statistics*

Physiological Outcome Measure	**Group**	**Pre-Test Mean (*sd*)**	**Post-Test Mean (*sd*)**	**F-Statistic**	**DF**	**Significance**	**Effect Size**
RMSSD	Control	52.9 (± *31.7*)	45 (± *26.9*)	.27	2,34	$p = .80$	$\eta^2 = .02$
	Meditation	54.7 (± *39.6*)	58.9 (± *25.7*)				
	Yoga	60.4 (± *44*)	53.2 (± *40.3*)				
LFHF	Control	1.2 (± *1*)	1.3 (± *1.1*)	1.3	2,34	$p = .30$	$\eta^2 = .07$
	Meditation	1.5 (± *1.1*)	1.2 (± *1.1*)				

	Yoga	1.2 (± *1.3*)	1.7 (± *1.5*)				
Frontal Alpha EEG Power	Control	-2.3 (± *1.4*)	-4.7 (± *.91*)	.66	2,26	*p* = .53	η^2 = .01
	Meditation	-2.9 (± *1.1*)	-4.6 (± *.95*)				
	Yoga	-3 (± *1.5*)	-4.4 (± *1*)				
Frontal Theta EEG Power	Control	-1.6 (± *1.5*)	-3.7 (± *1.1*)	.65	2,24	*p* = .53	η^2 = .03
	Meditation	-2.3 (± *1.2*)	-3 (± *1.3*)				
	Yoga	-2.5 (± *1.6*)	-3.2 (± *.94*)				

Note: RMSSD, Root mean square of successive differences; LFHF, Low frequency high frequency ratio; Average frontal alpha and theta EEG power; Pre-Test Means, Post-Test Means; F-Statistic from rm-ANOVA; DF, Degrees of Freedom; P-value, Value of significance; Effect size represented by eta squared (η^2)
**** F-Statistic, DF, P-Value, and Effect size are provided for the Group x Time Interactions**

Secondary Outcomes Measures

Physical Fitness and Health Measurements

Weight. The rm-ANOVA did not reveal a significant Group x Time interaction ($F(2,36) = .52$, $p = .60$), nor a significant main effect of Time ($F(1,36) = 3.69$, $p = .06$) or significant main effect of Group ($F(2,36) = 1.59$, $p = .22$).

Body Fat Percentage. The rm-ANOVA evaluating the effect of Time and Group on body fat percentage did not show a Group x Time interaction ($F(2,36) = .28$, $p = .76$) or main effect of Group ($F(2,36) = 1.13$, $p = .33$); but did reveal a significant main effect of Time ($F(1,36) = 15.73$, $p < .001$). Body fat percentage increased significantly over time regardless of group.

Systolic and Diastolic Blood Pressure. The rm-ANOVA evaluating the effect of Time and Group on systolic blood pressure did not reveal a significant Group x Time interaction ($F(2,36) = 2.53$, $p = .11$), main effect of Time ($F(1,36) = .47$, $p = .50$), or main effect of Group ($F(2,36) = .54$, $p = .12$). Additionally, the rm-ANOVA evaluating the effect of Time and Group on diastolic blood pressure did not reveal a significant Group x Time interaction ($F(2,36) = .24$, $p = .79$), main effect of Time ($F(1,36) =2.85$, $p = .10$), or main effect of Group ($F(2,36) = .47$, *p*

= .63). While not significant, the yoga and meditation groups exhibited a decrease in systolic blood pressure while the control group exhibited an increase.

Resting Heart Rate. The rm-ANOVA evaluating the effect of Time and Group on resting heart rate did not reveal a significant Group x Time interaction ($F(2,36) = .78$, $p = .47$) or main effect of Group ($F(2,36) = .27$, $p = .77$); but did reveal a significant main effect of Time ($F(1,36) = 6.83$, $p = .013$). Over time, from pre-test to post-test, there was a decrease in resting heart rate regardless of group.

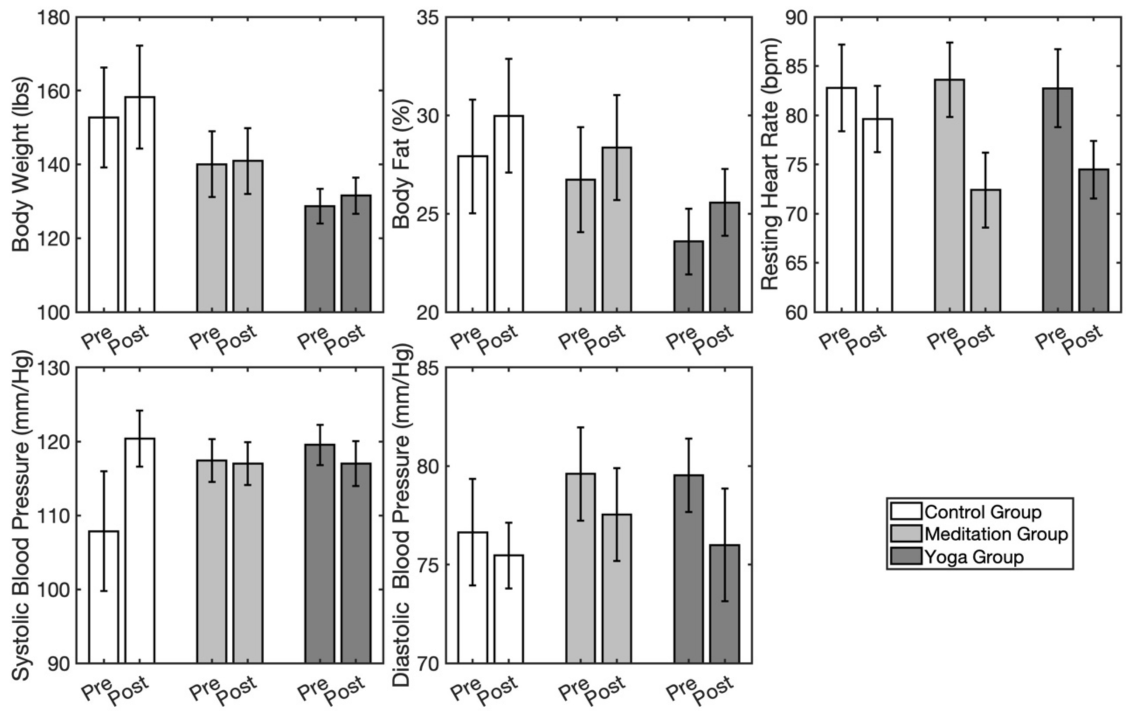

Figure 6. *Changes in Measured Body Composition (Body Weight, Body Fat Percentage) and Vital Signs (Resting Heart Rate, Systolic Blood Pressure, Diastolic Blood Pressure) from Pre- to Post-Test.* The group means are represented by each bar, pre and post, with standard error shown.

Hand Grip Strength. The rm-ANOVA evaluating the effect of Time and Group on hand grip strength did not reveal a significant Group x Time interaction ($F(2,36) = .73$, $p = .49$), main effect of Time ($F(1,36) = .03$, $p = .86$), or main effect of Group ($F(2,36) = .49$, $p = .62$)

Curl-Ups. The rm-ANOVA evaluating the effect of Time and Group on curl-ups did not reveal a significant Group x Time interaction ($F(2,36) = .35$, $p = .56$), main effect of Time ($F(1,36) = .35$, $p = .56$), or main effect of Group ($F(2,36) = .22$, $p = .81$).

Push-Ups. The rm-ANOVA evaluating the effect of Time and Group on push-ups did not reveal a significant Group x Time interaction ($F(2,36) = .59$, $p = .56$), main effect of Time ($F(1,36) = .38$, $p = .54$), or main effect of Group ($F(2,36) = .45$, $p = .64$).

Sit-and-Reach Flexibility. The rm-ANOVA evaluating the effect of Time and Group on sit-and-reach flexibility did not reveal a significant Group x Time interaction ($F(2,36) = .20$, $p = .82$) or main effect of Group ($F(2,36) = .76$, $p = .48$); but did reveal a significant main effect of Time ($F(1,36) = 4.35$, $p = .044$). Sit and reach distance increased over time regardless of group.

Shoulder Stretch Flexibility. The rm-ANOVA evaluating the effect of Time and Group on shoulder stretch flexibility did not reveal a significant Group x Time interaction ($F(2,36) = 2.27$, $p = .12$), main effect of Group ($F(2,36) = 3.10$, $p = .06$), or main effect of Time ($F(1,36) = .75$, $p = .39$).

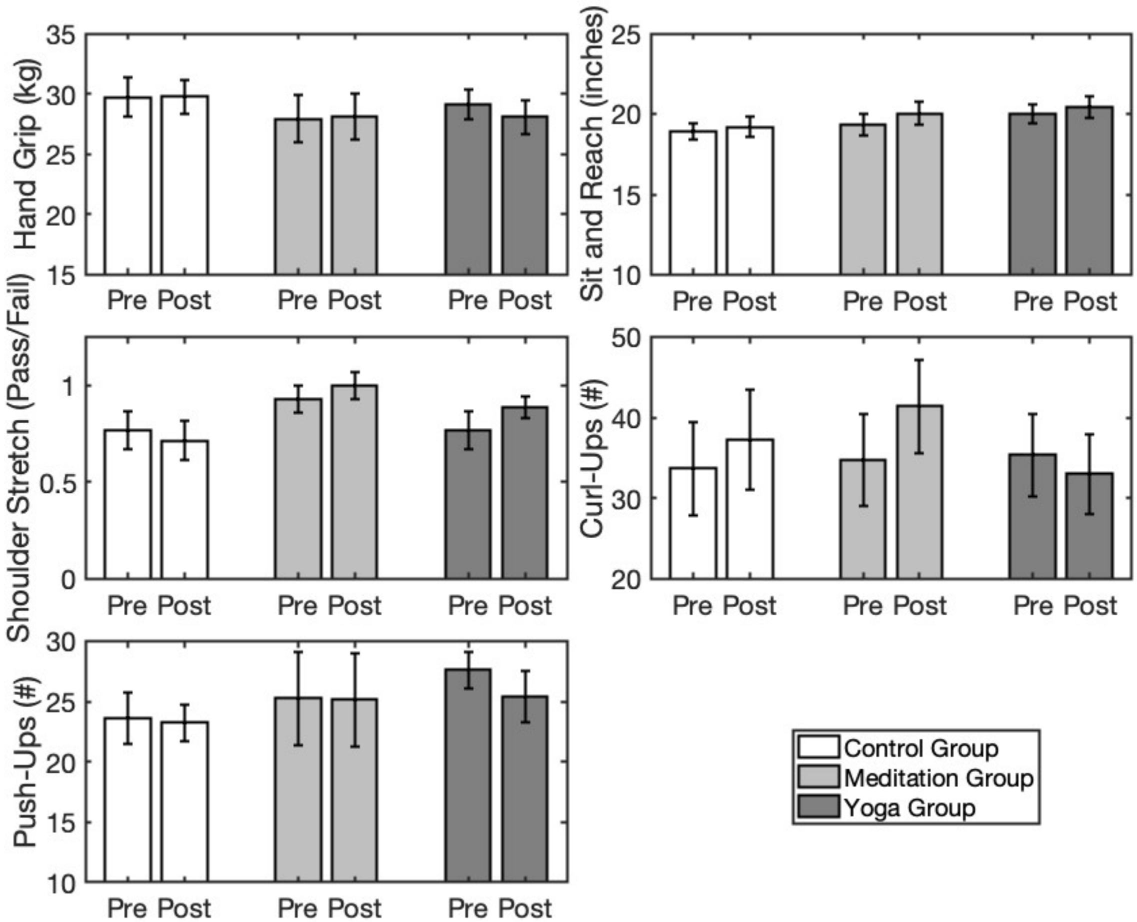

Figure 7. *Changes in Performance Based Physical Fitness Measurements (Hand Grip Strength, Back Saver Sit-and-Reach, Shoulder Stretch, PACER Curl-Ups, Push-Ups) from Pre- to Post-Test.* The group means are represented by each bar, pre and post, with standard error shown.

Table 8. *Pre- and Post-Test Physical Fitness Outcome Statistics*

Physical Health Outcome Measure	Group	Pre-Test Means (*sd*)	Post-Test Means (*sd*)	F- Statistic	DF	P-Value	Effect Size
Weight (lbs.)	Control	152.8 (± *50.7*)	158.2 (± *52*)	.52	2,36	p = .60	$\eta^2 = .03$
	Meditation	140 (± *34.5*)	140.9 (± *37.2*)				
	Yoga	128.7 (± *18.4*)	131.6 (± *19*)				
Body Fat (%)	Control	27.9 (± *10.8*)	29.9 (± *10.8*)	.28	2,36	p = .76	$\eta^2 = .01$
	Meditation	26.7 (± *10.3*)	28.4 (± *10.1*)				

	Yoga	23.6 (± *6.4*)	25.6 (± *6.6*)				
Systolic Blood Pressure (mm/Hg)	Control	107.9 (± *30.4*)	120.4 (± *14.1*)	2.3	2,36	p = .12	$\eta^2 = .12$
	Meditation	117.4 (± *11.3*)	117 (± *11.9*)				
	Yoga	119.5 (± *10.6*)	117 (± *11.7*)				
Diastolic Blood Pressure (mm/Hg)	Control	75.6 (± *10.1*)	75.5(± *6.2*)	.24	2,36	p = .79	$\eta^2 = .01$
	Meditation	79.6 (± *9.1*)	77.5 (± *10.2*)				
	Yoga	79.5 (± *7.2*)	76 (± *11.1*)				
Resting Heart Rate (bpm)	Control	82.8 (± *16.5*)	79.6 (± *12.5*)	.78	2,36	p = .47	$\eta^2 = .04$
	Meditation	83.6 (± *14.7*)	72.4 (± *16*)				
	Yoga	82.7 (± *15.3*)	74.5 (± *11.3*)				
Hand Grip Strength (kg)	Control	29.7 (± *6.1*)	29.8 (± *5.1*)	.73	2,36	p = .49	$\eta^2 = .04$
	Meditation	27.9 (± *7.5*)	28.1 (± *6.1*)				
	Yoga	29.1 (± *4.9*)	28.1 (± *5.4*)				
Curl-Ups (#)	Control	33.7 (± *21.6*)	37.2 (± *23.2*)	.54	2,36	p = .59	$\eta^2 = .03$
	Meditation	34.7 (± *22.2*)	41.1 (± *23.3*)				
	Yoga	35.4 (± *19.3*)	33 (± *19.4*)				
Push-Ups (#/minute)	Control	23.9 (± *7.8*)	23 (± *5.5*)	.59	2,36	p = .56	$\eta^2 = .03$
	Meditation	25.6 (± *15.2*)	24.8 (± *14.9*)				
	Yoga	27.7 (± *6*)	27 (± *8.5*)				
Sit-and-Reach Flexibility (inches)	Control	18.9 (± 1.*9*)	19.2 (± *2.4*)	.20	2,36	p = .82	$\eta^2 = .01$
	Meditation	19.3 (± *2.6*)	20.4 (± *2.4*)				
	Yoga	19.9 (± *2.2*)	20.4 (± *2.6*)				
Shoulder Reach Flexibility (Pass/Fail)	Control	.77 (± *.37*)	.71 (± *.38*)	2.27	2,36	p = .12	$\eta^2 = .12$
	Meditation	.93 (± *.27*)	1 (± *0*)				
	Yoga	.77 (± *.37*)	.88 (± *.22*)				

Note: Pre-Test Means, Post-Test Means; F-Statistic from rm-ANOVA; DF, Degrees of Freedom; P-value, Value of significance; Effect size represented by eta squared (η^2); C = Control Group, M = Meditation Group, Y = Yoga Group

**** F-Statistic, DF, P-Value, and Effect size are provided for the Group x Time Interactions**

Chapter 5: Discussion and Limitations

Discussion

The present study is the first to comprehensively evaluate the effects of a Hatha yoga and meditation intervention (10 weeks, 2x/week) on physiological (EEG and HRV) and behavioral outcomes (mental and physical health). Overall, there were significant improvements in anxiety (BAI) across time regardless of group, depression (BDI and DASS-21 depression) for the meditation group, and stress (DASS-21 stress) for the meditation and yoga groups. Contrary to the hypotheses, all groups showed a similar decrease in average frontal alpha and theta EEG power. There were no differences in the HRV outcome measures (RMSSD and LFHF) by time or group as well. Lastly, with regards to the physical fitness measures, surprisingly there was a significant increase in body fat percentage and sit and reach flexibility and a significant decrease in resting heart rate across time regardless of group. While some of the analyses did not provide support for our a priori hypotheses, this study represents an important first step in comprehensively evaluating the effects of long-term participation in Hatha yoga and meditation using a strong study design.

With respect to the first hypothesis, the present results provide limited support that chronic participation in Hatha yoga leads to improvements in mental health outcomes. Specifically, participation in 45 minutes of Hatha yoga twice a week for at least 10 weeks was associated with decreased stress from pre- to post-test. Although the control group did not show a significant reduction in stress, the meditation and Hatha yoga groups did significantly reduce stress from pre- to post-test. Moreover, the meditation group also exhibited a significant reduction in depression (BDI and DASS depression); the yoga and control groups did not exhibit significant reductions in depression. Although, the BDI scores did show a decrease in depression symptoms from pre- to post-test regardless of group. Lastly, there was a significant reduction in anxiety symptoms (BAI) from pre- to post-test regardless of group, suggesting that the interventions did not uniquely contribute to anxiety reductions. Taken together, long-term participation in meditation appears more beneficial than Hatha yoga in young adults with elevated mental health symptoms.

The present results do not fully align with a previous study that found that participation in yoga results in a significant reduction in anxiety. Specifically, Lemay et al. (2019), reported a significant decrease in BAI scores of 20 college students following a six-week (1x/week, 60-minutes) Vinyasa yoga intervention. Similarly, Shohani et al. (2018) reported a significant decrease in DASS-21 anxiety scores following a 4-week (3x/week, 60-70-minutes) Hatha yoga intervention. However, both Lemay et al. (2019) and Shohani et al. (2018) employed a single group pre-post design and thus, changes in BAI and DASS-21 anxiety scores, respectively, cannot be uniquely attributed to the intervention. The present study employed a strong study design – a randomized control design with "active" and "true" control groups. Although the present study observed a decrease in BAI for the Hatha yoga group, the other groups also showed a reduction in anxiety scores over time. Thus, it's possible that the anxiety reduction reported previously may not be uniquely attributed to yoga. Additionally, the previous studies included both yoga and meditation in the interventions. Thus, it was not possible to parse the unique effects of the intervention in yoga or meditation. In contrast, the study design employed presently, allowed us to parse differences between yoga and meditation (and a control group).

With respect to depression, contrary to the a priori hypotheses and results from previous studies, there was a decrease in depression symptoms (BDI) over time regardless of group, however, only those in the meditation group exhibited significant decreases in BDI scores.

Additionally, the DASS-21 depression subscale scores supported these results, showing a significant decrease in depression symptoms for only the meditation group. In one previous study (Chu et al., 2017), depressed women were randomized into either 12 weeks (2x/week, 60-minutes) of Hatha yoga or a control group. The yoga group exhibited a significant decrease in BDI scores from pre-test to post-test, while the control group exhibited no such change (Chu et al., 2017). Maddux et al. (2017) and Papp et al. (2019) also found significant decreases in depression following a 6-week and a 16-week yoga intervention, compared to control groups (Maddux et al., 2018; Papp et al., 2019). However, these studies utilized the Hospital Anxiety and Depression Scale (HADS) as a measure of depression, and Maddux et al. (2017) employed a different form of yoga (power yoga). In addition, Shohani et al., (2018) also found significant decreases in depression using the DASS-21 depression scores following a 4-week Hatha yoga intervention. The discrepancy between the previous studies and the present study may be separating meditation from the Hatha yoga poses as separate interventions. The meditation practice included as part of the yoga practiced in the previous studies may have driven changes in depression scores.

Scores from the DASS-21 anxiety subscale are consistent with a reduction in anxiety symptoms regardless of group. Indeed, this is what the BAI results show, and the DASS-21 anxiety subscale is in the same direction with a significance level close to reaching the alpha level for the present study. These results also indicate that meditation may be more beneficial for anxiety symptoms compared to Hatha yoga, again, a similar trend to that of anxiety symptoms measured by the BAI. Shohani et al., (2018) did reveal a significant decrease in DASS-21 anxiety scores following a 4-week (3x/week, 60-70-minutes) Hatha yoga intervention, however, the study design was a single group pre-post and did not compare to an active control or control group. Thus, as mentioned previously, more research is needed to determine the efficacy of Hatha yoga on anxiety symptoms, particularly compared to an active control or control group.

In the present study, the meditation group exhibited significantly lower DASS-21 depression scores from pre-test to post-test compared to the control and yoga groups. The yoga group showed a non-significant decrease in DASS-21 depression scores, while the control group showed a non-significant increase in DASS-21 depression scores. Shohani et al., (2018) also found significant decreases in DASS-21 depression scores following a Hatha yoga intervention. Again, the Shohani et al., (2018) study did not compare Hatha yoga to an active control or control group, so as previously stated, the incorporation of meditation with the practice of poses in each yoga session may have driven the changes in depression symptoms (Shohani et al., 2018).

Results for the DASS-21 stress subscale fully supported the a priori hypotheses regarding stress symptoms. There was an overall decrease in stress symptoms over time. regardless of group, however, only the meditation and Hatha yoga groups exhibited a significant decrease in stress symptoms compared to the control group. For example, Shohani et al. (2018) reported a significant reduction in DASS-21 stress scores from pre-test to post-test, but again, this study employed a one-group pre-post design. Others have reported reduced stress scores (Perceived Stress Scale) following a 12-week (2x/week, 60-minutes) Hatha yoga intervention (Chu et al., 2017), 6-week (1x/week, 60-minutes) Vinyasa yoga intervention (Lemay et al., 2019), 16-week (2x/week, 60-minutes) power yoga intervention (Maddux et al., 2018), and a six-week (1x/week, 90 minutes) combined Vinyasa yoga and meditation intervention (Papp et al., 2019). However, taken together, different forms of yoga in combination with meditation (previous studies) and meditation alone (present study) appear effective means of reducing stress symptoms.

Across time, there was a significant reduction in DASS-21 total scores regardless of group, however, only the meditation group exhibited a significant decrease in DASS total score compared to the control and Hatha yoga group. Thus, these results indicate a decrease in internalizing symptoms experienced in young adults following a 10-week (2x/week, 45-minutes) meditation intervention. The results for the DASS-21 total scores do indicate a decrease in the Hatha yoga group, however, this Group x Time interaction failed to reach significance. Yi et al., (2022) also found decreases in DASS-21 total score following a long-term Kripalu yoga intervention (12 weeks, 1 session/2 weeks, 45-minutes; Yi et al., 2022), a much gentler form of Hatha yoga. However, this population was motor vehicle accident survivors with PTSD which does not apply to the specific aims of the present study. Therefore, different forms of yoga, specifically Hatha yoga and those derived from Hatha yoga, may indeed result in decreases in DASS-21 total scores, however, more research is needed on the effects of long-term yoga interventions on overall internalizing symptomology, or general mental health as measured by the DASS-21 total score. Lastly, it is important to consider that the results for the DASS-21 depression and stress subscale scores may have driven the overall results for the DASS-21 total scores.

In summary, these behavioral results suggest that the meditation intervention was more effective in reducing self-reported mental health symptoms compared to the Hatha yoga intervention. From a translational perspective, these results are important and clinically relevant as the meditation intervention may be more accessible given it is less physically demanding than Hatha yoga and could be practiced individually at home. Indeed, participating in meditation may address personal barriers to treatment experienced with mental health burdens (treatment inertia). Moreover, the present results are generalizable to individuals experiencing internalizing symptoms but may not meet the clinical criteria needed to access treatment options. Indeed, changes in the DASS-21 depression and stress scales were observed, suggesting that the overall symptom burden was lessened through participation in meditation.

Inhibitory Brain Activity and Cognitive Control: Frontal Alpha and Theta Spectral Power

Concerning the physiological changes, the second hypothesis was not supported; participants exhibited significant decreases in average frontal alpha and theta power regardless of group. There is only one other study that measured frontal alpha and theta power following a Hatha yoga intervention (8-weeks, 3x/week, 60-minutes); the yoga group exhibited an increase in frontal theta power and frontal alpha power compared to the control group (Ajjimaporn et al., 2018). The participants in that study reported physical disability-related stress and the intervention was modified Hatha yoga (Ajjimaporn et al., 2018). Given the discrepancy between the previous research and the present study, more research is needed to evaluate the effects of chronic participation in yoga and meditation on EEG spectral power. Indeed, the effects of an acute bout of meditation or yoga on EEG alpha and theta power appear more consistent in the literature. For example, Bhaskar et al. (2020) reported greater alpha and theta power following an acute bout of meditation. A pilot study conducted within our lab (Lang et al., In Preparation) and Field et al. (2010) reported greater alpha and theta power following an acute bout of Hatha yoga and a Vinyasa style yoga, respectively. The results from the pilot study (Lang et al., In Preparation) may have been driven by participants having elevated mental health symptoms at baseline which is important to consider. However, on the contrary, the participants in the Bhaskar et al, (2020) and Field et al., (2010) study were not experiencing elevated mental health symptoms at baseline. Further, the Bhaskar et al., (2020) and Field et al., (2010) study measured EEG individually (one-on-one), while the pilot study (Lang et al., In Preparation) was a group-based data collection. Therefore, it does seem that the results remain consistent across acute studies.

It is important to note that there were technical issues associated with conducting a group yoga or meditation session with EEG (and HRV data collection). To connect participants correctly to their MUSE and HRV applications and iPad via Bluetooth, each participant had to be carefully connected one at a time. It took at least two to five minutes for each participant to be connected, which was a time-demanding process and prolonged the overall time of pre-and post-test. Although steps were taken to reduce wait time associated with connecting the MUSE devices during the group session (i.e., at least one research assistant per participant, splitting the pre- and post-testing across two days), the data collection did not proceed until all participants were connected (~ 15-20 minutes). The longer wait time associated with connecting all participants may have affected the EEG results. Moreover, Sachs et al., (2004) found that individuals with elevated anxiety and depression showed consistently decreased frontal alpha and theta power compared to those with lower levels of anxiety and depression and the control (Sachs et al., 2004). Therefore, the EEG results may have also been driven by participants with elevated levels of anxiety and depression. Another potential explanation for the lack of systematic changes in EEG power across groups is that the participants in the present study were selected because of their self-reported internalizing symptoms. Lastly and most important to consider, while the intervention could have collected the EEG data before and after the first and last sessions of yoga and meditation, this was not the case, and the EEG data was collected before the first yoga and meditation sessions and after the last yoga and meditation sessions. Thus, there may have been an effect of the methodology of data collection on the EEG results.

Parasympathetic Dominance and Behavioral Flexibility: LFHF and RMSSD

Concerning the physiological changes in HRV, the third hypothesis was not supported. There were no changes in LFHF suggestive of increased behavioral flexibility or RMSSD suggestive of increased vagal tone by group or time. Despite there being no significant changes across time or group, the meditation group did exhibit non-significant increases in (Δ + 4.2 ms) and decreases in LFHF (Δ - .03) from pre-test to post-test. The present results are consistent with previous studies that also found no significant change in RMSSD following a 12-week (2x/week, 85-minutes) Vinyasa yoga intervention (Elstad et al., 2020) or a 16-week (16-weeks, 3-5x/week, 45-50-minutes) Bikram yoga intervention (Hewett et al., 2017). However, Meshram and Meshram (2020) did observe a significant increase in RMSSD following a 6-month (5x/week, 35-minutes) yoga intervention (style unspecified), which suggests perhaps a much larger dose of yoga practice is needed to impact RMSDD. However, the study employed a one-group pre-test post-test design and it's possible that the change observed is not specific to yoga practice.

Concerning LFHF, Hewett et al. (2017) also did not observe a significant decrease in LFHF following a 16-week Bikram yoga intervention. Rather, both the control and yoga groups exhibited increases in LFHF. Meshram and Meshram (2019) did observe a significant decrease in LFHF following a 6-month yoga intervention. But, again, the dose of their intervention was much larger than the present and previous studies and they employed a weak study design, which reduces the internal validity of the study.

Taken together, more comprehensive research is needed to evaluate the long-term effects of various forms of yoga on time- and frequency-domain indices of HRV. Moreover, a more targeted focus on meditation with asana practice may be more effective for significantly increasing behavioral flexibility and parasympathetic dominance, as indicated by the exploratory analyses in the present study. Lastly, like the methodological concerns with the EEG data collection, the HRV results may be due to the physiological data collection method of the present study. Specifically, the data was collected before the first yoga and meditation sessions and after the last yoga and meditation sessions instead of before and after the first and last sessions.

Physical Fitness

In the present study, there were significant increases in body fat percentage ($p < .001$) and sit and reach flexibility ($p = .04$), and significant decreases in resting heart rate ($p = .01$) from pre- to post-test regardless of group. However, there were no other significant physical fitness outcomes (i.e., body weight, blood pressure, shoulder flexibility, hand grip strength, curl-ups, and push-ups) following the 10-week Hatha yoga and meditation interventions. In their review of the yogic literature, Field (2011) found similar results across the literature regarding lower body flexibility (sit and reach flexibility) and resting heart rate, such that following long-term yoga interventions there were significant increases in lower body flexibility and significant decreases in resting heart rate (Field, 2011). To note, these results were not seen across all the study groups, but rather in comparison to the control groups in the study. Opposite from our findings however, Field (2011) found that across multiple studies evaluating long-term yoga interventions, there were significant decreases in body fat percentage, as well as significant decreases in blood press ure, and significant increases in muscular strength (Field, 2011).

Many of the current Hatha yoga interventions leading to significant improvements in flexibility (Gothe & McAuley, 2016; Grabara & Szopa, 2015; Vanfraechem et al., 2014), and muscular strength (Gothe & McAuley, 2016) included older populations (i.e., 50-80 years old). Although these results would indicate Hatha yoga as an effective intervention for improving strength and flexibility, the population included (i.e., older adults) had a larger room for improvement in these physical fitness outcomes than the present population (i.e., younger adults). Additionally, yoga studies evaluating the effects of other forms of yoga on physical fitness measurements such as muscular strength (Ni et al., 2014) and anthropometrics (Hewett et al., 2017) in young adults utilized more sensitive measurement tools compared to the present study (i.e., electromyography, maximal voluntary contraction; (Ni et al., 2014), dual x-ray absorptiometry scans; Hewett et al., 2017). In conclusion, the dosage of our Hatha yoga and meditation interventions were not enough to elicit significant fitness effects, which may indeed be contributed to the overall health of the population, the sensitivity of our measurement tools, and the duration of the intervention.

Conclusions, Limitations, and Future Directions

Although we hypothesized that the Hatha yoga intervention would have the greatest impact on internalizing symptoms and physiological outcomes, the present results suggest that 10 weeks of meditation significantly reduced depression, stress, and overall mental health symptoms compared to Hatha yoga and a control group. While there are limitations to the present study, the results show promise that meditation could be employed as an alternative or complementary treatment for individuals with elevated mental health symptoms. Although the results from the Hatha yoga group did not reach statistical significance, there were similar trends observed. A larger and more heterogenous sample, longer intervention duration, or other factors may influence the efficacy of Hatha yoga on internalizing symptoms. Ultimately, more research is necessary to replicate and extend the present findings. Future research should maintain methodological rigor, compare various forms of yoga, and employ active control and typical control groups.

While this study is the first to evaluate EEG and HRV with mental health outcomes, it is not without limitations. Primarily, the physiological data (i.e., EEG and HRV) was taken at two time points, once before the first session and once after the last session. Further, the physiological data for the control group was not taken after yoga or meditation sessions and was collected one-on-one instead of in a group-based design. As such, any differences in the physiological data (e.g., time main effect in alpha and theta power) may be due to an acute effect of yoga and meditation following the last session. It is also possible that the results may be due to the group-based nature of data collection. Future research aimed at examining the chronic effects of yoga or meditation should collect physiological data before and after both the first and last sessions to account for acute and chronic changes in the physiological outcomes. Increases in alpha and theta band power and decreases in LFHF, were observed in our pilot acute study and Field et al. (2010). These expected outcomes were not observed in the long-term intervention. Therefore, the timing of physiological data collection may not have been influenced by an acute effect.

Meshram and Meshram (2019) employed a similar data collection procedure – they collected HRV data before the first session and after the last session. They observed a significant increase/decrease in RMSSD and LFHF following a 6-month intervention (Meshram & Meshram, 2019). Moreover, Komiyama et al., (2021) found that acute light-to-moderate intensity exercise led to significant increases in alpha power and that this was synergistic with an eyes-closed resting condition (Komiyama et al., 2021). Similarly, Basso and Suzuki (2017) reviewed the effects of acute exercise on EEG markers and found that theta power also increases following an acute bout of exercise. Therefore, it is more likely that other factors (e.g., long wait time following session completion and data collection, lack of statistical power, and lack of exercise effects) affected the physiological results more significantly than the data collection method.

Additionally, the present study did not evaluate overall participation and attendance as a covariate or moderating variable. There may have been a relationship between the number of sessions attended and changes across all outcomes (internalizing symptoms, EEG, HRV, fitness). Future studies and analyses are needed to evaluate the dose needed to incur benefits across outcome measures for Hatha yoga and meditation interventions. Lastly, the heterogeneity and size of the sample are a limitation of the present study. Although the present study had a sample size larger than previous studies within the yogic literature (Albracht-Schulte & Robert-Mccomb, 2018; Bhaskar et al., 2020; Field et al., 2013; Harne & Hiwale, 2018; Telles et al., 2009), the sample was homogenous in terms of gender and age (i.e., predominantly white females between the ages of 18 and 21) and the sample size (N = 44) did have 80% statistical power, but only to detect large effect sizes. Indeed, the significant mental health results of the present study revealed large effect sizes, while the physiological and physical fitness results revealed small to medium effect sizes. Therefore, a more heterogeneous sample size would result in greater internal validity, and a larger sample would result in more informative results regarding smaller effects of Hatha yoga and meditation interventions on the primary outcome measures.

Moving forward with this line of research, future studies should first evaluate long-term Hatha yoga interventions that incorporate both poses and meditation, a group that only includes meditation and a control group. Additionally, more than one form of yoga should be compared to each other and a control to determine the most effective form of yoga on behavioral and physiological outcomes. Further, participants in all three groups were either taking medication or receiving therapy, both of which may have contributed to the behavioral and physiological outcome measures. Indeed, additional analyses and research are needed to further evaluate the effect of therapy and/or medication on both behavioral (mental health) and physiological (EEG and HRV) outcomes. Moreover, additional analyses should also be conducted to examine the potential additive effect of Hatha yoga or meditation and anti-anxiety medication on mental health scores over time. To this point, future studies may benefit from qualitative analysis that could extrapolate on the duration of the medication use before yoga and meditation; and then evaluate the combined effects of adding a yoga or meditation intervention on both behavioral and physiological outcomes. Lastly, future research must collect physiological data before and after the first and last intervention sessions to systematically, and with sound methodology evaluate the responsivity of such EEG and HRV markers.

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Appendix A: Approved IRB Protocol

Revised 06/09/2022

1

AUBURN UNIVERSITY HUMAN RESEARCH PROTECTION PROGRAM (HRPP)

REQUEST for MODIFICATION

For Information or help completing this form, contact: **The Office of Research Compliance (ORC)**
Phone: **334-844-5966** E-Mail: **IRBAdmin@auburn.edu**

- **Federal regulations require IRB approval before implementing proposed changes.**
- **Change means any change, in content or form, to the protocol, consent form, or any supportive materials (such as the investigator's Brochure, questionnaires, surveys, advertisements, etc.). See Item 4 for more examples.**

1. Today's Date	8/10/2022

2. Principal Investigator (PI) Name: Melissa Pangelinan			
PI's Title:	Associate Professor	**Faculty PI (if PI is a student):**	Click or tap here to enter text.
Department:	Kinesiology	**Department:**	Click or tap here to enter text.
Phone:	334-744-4142	**Phone:**	Click or tap here to enter text.
AU-E-Mail:	Mgp0020@auburn.edu	**AU E-Mail:**	Click or tap here to enter text.
Contact person who should receive copies of IRB correspondence (Optional):	Danielle Lang	**Department Head Name:**	Mary Rudisill
Phone:	610-780-4405	**Phone:**	334-750-4059
AU E-Mail:	Dmc0046@auburn.edu	**AU E-Mail:**	rudisme@auburn.edu

3. AU IRB Protocol Identification		
3.a. Protocol Number: 18-111 EP 1804		
3.b. Protocol Title: Effects of group fitness and yoga on student mental and physical health		
3. c. Current Status of Protocol – For active studies, check ONE box at left; provide numbers and dates where applicable		
☐	**Study has not yet begun; no data has been entered or collected**	
☒ ☐ ☐ ☐	**In progress If YES, number of data/participants entered:** 195 **Is this modification request being made in conjunction with/as a result of protocol renewal?** ☐ **YES** ☒ **NO** **Adverse events since last review If YES, describe:** Click or tap here to enter text. **Data analysis only**	**Current Approval Dates** **From:** Click or tap to enter a date. **To:** Click or tap to enter a date.
☐	**Funding Agency and Grant Number:** Click or tap here to enter text.	**AU Funding Information:** Click or tap here to enter text.
☐	**List any other institutions and/ or AU approved studies associated with this project:** Click or tap here to enter text.	

Page 1

Google Drive Link to Appendix A

Appendix B: Therapies and Medications Questionnaire

Pediatric Movement and Physical Activity Lab
School of Kinesiology - Auburn University

MOVEMENT. HEALTH. PERFORMANCE.

Therapies and Medications Questionnaire

1. Are you currently seeking treatment for mental health issues related to anxiety, stress or depressive symptoms? If no, skip to question 4.
   a. Yes
   b. No

2. If yes, how often do you attend therapy sessions (e.g., 1x/week, 2x/month, etc.)?

   ____

3. Who leads your therapy sessions (e.g., counselor, therapist, psychologist, psychiatrist, etc.)?

   ____

4. Are you taking any medications related to anxiety, stress, or depression issues? If no, skip to question 5.
   a. Frequency ______________________________
   b. Dose ______________________________
   c. Drug Name ______________________________

5. Are you taking any herbal supplements related to anxiety, stress, or depression issues (e.g.,)? If no, skip to question 6.
   a. Frequency ______________________________
   b. Dose ______________________________
   c. Drug Name ______________________________

6. Do you feel that the treatment you are receiving has helped to reduce your levels of anxiety, stress, or depressive symptoms?
   a. Yes
   b. No

Google Drive Link to Appendix B

Appendix C: Mental Health Resource Packet

Local and Accessible Mental Health Resources

*As a reminder, if in crisis or emergency please call 9-1-1

"Today I refuse to stress myself out over things I can't control and change."

"Mental health is not a destination, but a process. It's about how you drive, not where you're going."

"On particularly rough days when I'm sure I can't possibly endure, I like to remind myself that my track record for getting through bad days so far is 100% and that's pretty good."

Online/Phone and Text Resources:

- Crisis Text Line: Text SIGNS to 741741 for 24/7, anonymous, free crisis counseling
- Disaster Distress Helpline: CALL or TEXT 1-800-985-5990 (press 2 for Spanish)
- The Trevor Project's TrevorLifeline: 1-866-488-7386
- Create your own profile at Anxiety Social Net (anxietysocialnet.com) to connect with people dealing with everything from social anxiety to agoraphobia. Prefer to meet in person? Find a state-by-state list of support groups at the Anxiety and Depression Association of America's website (adaa.org).
- Locate an in-person or online group at the Depression and Bipolar Support Alliance site (dbsalliance.org).
- After Silence (aftersilence.org) is a message board and chat room for victims of sexual violence.
- Eating Disorder Hope catalogs online support groups (eatingdisorderhope.com/recovery/support-groups/online).
- NEDA.com: Site for information on support groups and local events supporting those with and recovering from ED.
- Health Unlocked: A health-focused social network with communities for anxiety, depression, and other mental health issues. https://healthunlocked.com/.
- Turn 2 Me: https://turn2me.ie/ :Online support group for anxiety, depression, stress, and general mental health run by qualified professionals. Sessions are free, but require a reservation in advance.
- DailyStrength: https://www.dailystrength.org/; provides support groups for those struggling with many conditions.
- 7Cups: Free 24/7 chat with volunteer listeners. Monthly online counseling available with a licensed therapist for a fee. https://www.7cups.com/
- Mental Health Forum: Peer-to-peer community for a range of mental health issues, from anxiety to eating disorders. https://www.mentalhealthforum.net/

Google Drive Link to Appendix C

Appendix D: Physical Fitness Testing Instruction Sheets

Google Drive Link to Appendix D

TANITA Body Composition Scale

Instructions:

1) Instruct the participant to remove their shoes and socks.

2) Press the ON/OFF button.

3) Push 1 and then ENTER to enter 1lb for clothes weight.

4) Ask the participant if they consider themselves athletic. If the participant says yes, choose athletic. If they say no, or do not have an opinion, choose standard. Use your best estimate and when in doubt, select standard.

5) Press MALE or FEMALE to enter the participant’s sex.

6) Ask the participant how old they are and enter their AGE.

7) Enter the participant’s height in feet/inches (to nearest half-inch).

8) Wait for the light next to “STEP ON” to turn GREEN.

9) Instruct the participant to step onto the scale, with their feet on the silver metal plates, and stand as still as possible.

10) When the light flashes next to under/healthy/over and the paper starts to print, instruct the participant to step off the scale and wipe it down to prepare for the next participant.

Scoring: Record the requested information from the printout and attach the printout to the testing sheet.

[Google Drive Link to Appendix D]

Appendix E: Physical Activity Readiness Questionnaire for Everyone (PAR-Q+)

2015 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ OR high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ____________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it ***does not limit your current ability*** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Go to Page 4 to sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow International Physical Activity Guidelines for your age (www.who.int/dietphysicalactivity/en/).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at **www.eparmedx.com** before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

OSHF

 1 / 4
01-01-2015

Google Drive Link to Appendix E

Appendix F: Meditation Instructor Scripts

Instructor Script - *Ahimsa*

SEATED

1. Letter exercise
   a. Write a letter to your future self. Start with a greeting (as any letter should start) and say what you're about to undertake. State what things occupy your mind and time at this stage in your life. Ask yourself questions about what your future may hold: will you still be doing….will you still be worrying about…. End with a statement of self love to yourself as a reminder of what you love about yourself.
2. Breathing exercises
   a. Alternate nostril technique - breathing in through one nostril and out through the other
   b. 3 part breathing - inhale from base of spine to top of head and back down on exhale (pelvis to belly to chest)
   c. Ujjayi - Keep your mouth closed, constrict your throat to the point that your breathing makes a rushing noise, almost like snoring, control your breath with your diaphragm. Listen to the sound of breath between your ears.
   d. Mudra - bring each finger to thumb and apart on each inhale/exhale
   e. Box breathing - 4, then 6, then 8
   f. Color - think of something you want to bring into yourself. This could be a specific emotion or just positive vibes. Now, assign this feeling a color. There's no right or wrong answer here, but consider choosing a color you like or find soothing.
      1. Close your eyes and relax by breathing slowly and deeply.
      2. Visualize the color you've chosen.
      3. Continue breathing while holding that color in your thoughts, thinking about what it represents for you.
      4. With each inhale, imagine the desired color slowly washing over your body from head to toe. Continue breathing as you visualize the color filling your entire body, including your fingertips and toes.
      5. Imagine any unwanted emotions draining out of your body with each exhale, and replace them with your chosen color with each inhale.

LAYING DOWN

Google Drive Link to Appendix F

Appendix G: Meditation Session Takeaway Handouts

Takeaway Handout: Ahimsa

1. Questions
    a. How can we create a safe space in our minds and bodies?
    b. What practices do you have at home and in public to create a safe space?
    c. What is keeping you from finding this space?
    d. Do you live your life in a disciplined manner or as per your mood?
    e. Do you harm yourself in any way by either being too pushy or being too lazy?
    f. Do you deny your body rest when needed?
    g. Do you pay attention to your thoughts and breathing?
    h. Do you compare yourself to others?
    i. Do you base your self worth on whether you can do something or not?
2. How to apply Ahimsa into your daily life
    a. Cultivate the seeds of positive and loving thoughts
    b. Just let it go
    c. Whenever you hear that voice of negativity, of hatred and the violence that comes with it, make the conscious choice to silence it and replace it with something kind. Ahimsa in action is the practice of gentleness, compassion, understanding, patience, and love… Let me be patient today. Let me be understanding of a difficult situation, to actually be compassionate in a given circumstance.
    d. Practice Meditation
    e. But in the meantime, let us remember the butterfly effect that is responsible for the hurricane at a far away place just by fluttering its wings, know for sure that each kind gesture you make is not only strengthening you but also is creating an impact somewhere.

Google Drive Link to Appendix G

Appendix H: rm-ANOVA Assumption Testing Results and Corrections

Statistical Model	Independence	Normality	Sphericity
BDIPost-BDPre~Group x Time	X	X	X
BAIPost-BAIPre~Group x Time	X	X	X
DASSDepPost-DASSDepPre~Group x Time	X	Not Met	X
DASSAnxPost-DASSAnxPre~Group x Time	X	X	X
DASSStressPost-DASSStressPre~Group x Time	X	X	X
DASSTotalPost-DASSTotalPre~Group x Time	X	X	X
AlphaMeanPost-AlphaMeanPre x Time	X	X	X
ThetaMeanPost-ThetaMeanPre~Group x Time	X	X	X
LFHFMeanPost-LFHFMeanPre~Group x Time	X	X	X
RMSSDMeanPost-RMSSDMeanPre~Group x Time	X	X	X

Appendix I: Beck Depression Inventory (BDI)

Beck's Depression Inventory

This depression inventory can be self-scored. The scoring scale is at the end of the questionnaire.

1.
0 I do not feel sad.
1 I feel sad
2 I am sad all the time and I can't snap out of it.
3 I am so sad and unhappy that I can't stand it.

2.
0 I am not particularly discouraged about the future.
1 I feel discouraged about the future.
2 I feel I have nothing to look forward to.
3 I feel the future is hopeless and that things cannot improve.

3.
0 I do not feel like a failure.
1 I feel I have failed more than the average person.
2 As I look back on my life, all I can see is a lot of failures.
3 I feel I am a complete failure as a person.

4.
0 I get as much satisfaction out of things as I used to.
1 I don't enjoy things the way I used to.
2 I don't get real satisfaction out of anything anymore.
3 I am dissatisfied or bored with everything.

5.
0 I don't feel particularly guilty
1 I feel guilty a good part of the time.
2 I feel quite guilty most of the time.
3 I feel guilty all of the time.

6.
0 I don't feel I am being punished.
1 I feel I may be punished.
2 I expect to be punished.
3 I feel I am being punished.

7.
0 I don't feel disappointed in myself.
1 I am disappointed in myself.
2 I am disgusted with myself.
3 I hate myself.

8.
0 I don't feel I am any worse than anybody else.
1 I am critical of myself for my weaknesses or mistakes.
2 I blame myself all the time for my faults.
3 I blame myself for everything bad that happens.

9.
0 I don't have any thoughts of killing myself.
1 I have thoughts of killing myself, but I would not carry them out.
2 I would like to kill myself.
3 I would kill myself if I had the chance.

10.
0 I don't cry any more than usual.
1 I cry more now than I used to.
2 I cry all the time now.
3 I used to be able to cry, but now I can't cry even though I want to.

Google Drive Link to Appendix I

Appendix J: Beck Anxiety Inventory (BAI)

Beck Anxiety Inventory

Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by that symptom during the past month, including today, by circling the number in the corresponding space in the column next to each symptom.

	Not At All	Mildly but it didn't bother me much.	Moderately - it wasn't pleasant at times	Severely – it bothered me a lot
Numbness or tingling	0	1	2	3
Feeling hot	0	1	2	3
Wobbliness in legs	0	1	2	3
Unable to relax	0	1	2	3
Fear of worst happening	0	1	2	3
Dizzy or lightheaded	0	1	2	3
Heart pounding/racing	0	1	2	3
Unsteady	0	1	2	3
Terrified or afraid	0	1	2	3
Nervous	0	1	2	3
Feeling of choking	0	1	2	3
Hands trembling	0	1	2	3
Shaky / unsteady	0	1	2	3
Fear of losing control	0	1	2	3
Difficulty in breathing	0	1	2	3
Fear of dying	0	1	2	3
Scared	0	1	2	3
Indigestion	0	1	2	3
Faint / lightheaded	0	1	2	3
Face flushed	0	1	2	3
Hot/cold sweats	0	1	2	3
Column Sum				

***Scoring* -** Sum each column. Then sum the column totals to achieve a grand score. Write that score here ____________ .

Interpretation

A grand sum between **0 – 21** indicates very low anxiety. That is usually a good thing. However, it is possible that you might be unrealistic in either your assessment which would be denial or that you have learned to "mask" the symptoms commonly associated with anxiety. Too little "anxiety" could indicate that you are detached from yourself, others, or your environment.

A grand sum between **22 – 35** indicates moderate anxiety. Your body is trying to tell you something. Look for patterns as to when and why you experience the symptoms described above. For example, if it occurs prior to public speaking and your job requires a lot of presentations you may want to find ways to calm yourself before speaking or let others do some of the presentations. You may have some conflict issues that need to be resolved. Clearly, it is not "panic" time but you want to find ways to manage the stress you feel.

A grand sum that **exceeds 36** is a potential cause for concern. Again, look for patterns or times when you tend to feel the symptoms you have circled. Persistent and high anxiety is not a sign of personal weakness or failure. It is, however, something that needs to be proactively treated or there could be significant impacts to you mentally and physically. You may want to consult a counselor if the feelings persist.

Google Drive Link to Appendix J

Appendix K: Depression, Anxiety, and Stress Scale – 21 (DASS-21)

DASS 21 NAME ______________________________ DATE _______________

BLACK DOG INSTITUTE

Please read each statement and circle a number 0, 1, 2 or 3 which indicates how much the statement applied to you over the past week. There are no right or wrong answers. Do not spend too much time on any statement.

The rating scale is as follows:

0 Did not apply to me at all - NEVER
1 Applied to me to some degree, or some of the time – SOMETIMES
2 Applied to me to a considerable degree, or a good part of time – OFTEN
3 Applied to me very much, or most of the time - ALMOST ALWAYS

		Select 0 1 2 3	FOR OFFICE USE D	A	S
1.	I found it hard to wind down				
2.	I was aware of dryness of my mouth				
3.	I couldn't seem to experience any positive feeling at all				
4.	I experienced breathing difficulty (eg, excessively rapid breathing, breathlessness in the absence of physical exertion)				
5.	I found it difficult to work up the initiative to do things				
6.	I tended to over-react to situations				
7.	I experienced trembling (eg, in the hands)				
8.	I felt that I was using a lot of nervous energy				
9.	I was worried about situations in which I might panic and make a fool of myself				
10.	I felt that I had nothing to look forward to				
11.	I found myself getting agitated				
12.	I found it difficult to relax				
13.	I felt down-hearted and blue				
14.	I was intolerant of anything that kept me from getting on with what I was doing				
15.	I felt I was close to panic				
16.	I was unable to become enthusiastic about anything				
17.	I felt I wasn't worth much as a person				
18.	I felt that I was rather touchy				
19.	I was aware of the action of my heart in the absence of physical exertion (eg, sense of heart rate increase, heart missing a beat)				
20.	I felt scared without any good reason				
21.	I felt that life was meaningless				
		TOTALS	0	0	0

Google Drive Link to Appendix K