THE ACUTE EFFECTS OF VINYASA FLOW YOGA ON ARTERIAL STIFFNESS

by

Alexander Aaron Piña B.S.

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Committee Members:

Stacy D. Hunter, Chair

Junhyoung Kim

Lyn G. Litchke

DEDICATION

This is dedicated to my parents who made the ultimate sacrifice. Not once, but many times throughout my entire life to allow me to be in the position that I am today. Los quiero a los dos.

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LIST OF ABBREVIATIONS

Abbreviation	**Description**
CVD	Cardiovascular disease
AS	Arterial stiffness
cf-PWV	carotid femoral - pulse wave velocity
PWV	Pulse wave velocity
AIx	Augmentation index
AIx@75	Heart rate - corrected augmentation index
HR	Heart Rate
SBP	Systolic blood pressure
DBP	Diastolic blood pressure
MAP	Mean arterial pressure
PP	Pulse pressure

ABSTRACT

Arterial stiffness (AS) is a marker of subclinical atherosclerotic disease associated with reductions in the buffering capacity of the central, elastic arteries. Previous research has demonstrated reductions in AS with a relatively short-duration, 8-week Bikram (hot) yoga practice; however, the acute effects of yoga of any kind on this measure have not been investigated. PURPOSE: The aim of this study was to investigate the acute impact of one bout of Vinyasa flow yoga performed in thermoneutral conditions on indices of AS in healthy adults. METHODS: 30 apparently healthy adults ages 20-75 years with at least 3 months of yoga experience completed a one-hour Vinyasa flow yoga DVD. Seated blood pressure measures were obtained pre- and post-intervention. Augmentation index (AIx) and carotid-femoral pulse wave velocity (cf-PWV) were measured before and after the yoga session via applanation tonometry. AIx outcomes included crude Aix, AIx at a heart rate of 75 beats per minute (AIx@75), and peripheral AIx (P2/P1). As associations between negative mood states and impaired endothelial function, a determinant of AS, have been demonstrated previously, mood affect was assessed via Positive and Negative Affect Schedule (PANAS) 20-item survey before and after the Vinyasa session. RESULTS: After completion of the yoga DVD, significant reductions in AIx, and peripheral AIx ($P<0.05$ for all) were observed. AIx@75 ($P = .214$) and cf-PWV ($P = 0.628$) were unaltered. No significant changes in positive mood affect were observed; however negative mood affect significantly decreased ($P<0.05$) following the yoga session. CONCLUSION: These results highlight the efficacy of a single bout of hatha

yoga in improving central and peripheral indicators of arterial stiffness and provide insight into the potential effects of yoga in mediating CVD risk. These vascular changes were accompanied by significant reductions in negative affect, which could have contributed to reductions in AS by preventing exercise-induced endothelial dysfunction following the yoga bout.

I. INTRODUCTION

Cardiovascular disease (CVD) is the leading cause of death in the USA accounting for nearly 801,000 deaths each year while causing one out of every four deaths annually. (Mozaffarian et al. 2016). The global burden of CVD is extensive as evidenced by the estimated 17.5 million lives lost in 2012 alone and the estimated 31% of global deaths ascribed to this disease annually (CDC, 2013). CVD consists of several diseases including coronary artery disease (CAD), heart failure, hypertension, stroke, and atherosclerosis (Kendir, Akker, Vos, & Metsemakers, 2018). Arterial stiffness (AS) has been associated with the presence of CVD risk factors and atherosclerotic disease (Vlachopoulos, Aznaouridis, Stefanadis, 2010) and recognized as an independent predictor of stroke, CAD, and the development of hypertension (Mattace-Raso et al., 2006; Weber et al., 2004; Tsao et al. 2018). AS is also used as a vascular parameter utilized as a therapeutic target in both healthy and clinical populations, highlighting the need for research into the mediation of this parameter in healthy adults (Cameron et al., 2013).

AS refers to the properties of the arterial wall, which could potentially have functional consequences affecting the manner in which pressure, blood flow, and arterial diameter change during each cardiac cycle (Townsend et al., 2015). In a healthy elastic arterial system, high-pressure blood flow can be withstood by the arterial vessel wall through distention during each ventricular contraction (Lydakis et al., 2008; Heffernan et al., 2006). When arteries stiffen, the arterial wall lacks the ability to distend sufficiently and provide for the demand of blood flow needed, resulting in a higher generated blood pressure (Mak & Lai, 2015). Moderate- to high-intensity physical activity has been widely promoted as an effective method for preventing arterial stiffening (Anon, 1996; Haskell et al., 2007; Pinto et al., 2012). This suggests that the cardioprotective effect of exercise could be explained by a lowering effect on AS (Vaitkevicius et al., 1993; Blaire et al., 1995; McDonnell et al., 2013). AS is a marker of subclinical atherosclerotic disease present even in healthy, aging blood vessels and a predictor of all-cause mortality. This vascular parameter is thus utilized as a therapeutic target in both healthy and clinical populations (Vlachopoulos et al., 2010).

While the effects of resistance training and aerobic training on indices of AS have been investigated, the effects of yoga have not been thoroughly researched. Yoga has been described as a blend of physical exercise, controlled breathing, and relaxation practices (Siu et al., 2015). According to Grabara (2017), hatha yoga is a type of recreational physical activity consisting of slow and fast postures (asanas). Furthermore, hatha yoga classes may include breathing (pranayama) and relaxation exercises (Grabara, 2017). Grabara (2017) also emphasized Hatha's versatility, explaining its practicality and requirement of minimal equipment.

A style of Hatha yoga is Vinyasa, which involves continuous movement or flow through poses as opposed to participants holding poses isometrically for up to one minute as is the case in Bikram yoga (Baptiste, 2011). Another aspect of Vinyasa yoga is the focus on the sequence of asanas linked to each by flow and proper breathing (Fraser, 2007; Sherman et al., 2017). Vinyasa yoga usually includes a wide range of motions performed at a rapid pace, which increases the heart rates of practitioners and potentially benefits the cardiorespiratory and metabolic systems (Carroll et al., 2003; Mody, 2011).

While no studies have investigated the effects of Vinyasa yoga on arterial stiffness, Sherman et al. (2017) investigated the energy expenditure of Vinyasa flow yoga and concluded that it fit the criteria for “moderate intensity physical activity”. The current recommendation by the American College of Sports Medicine (ACSM) to elicit health benefits is moderate intensity physical activity for 30 min at least 5 days a week primarily in the form of aerobic activity. With moderate intensity physical activity providing benefits for CVD, diabetes, and cancer, Vinyasa yoga, also being a form of moderate-intensity exercise, could have similar health benefits.

Hunter et al. (2016) demonstrated that 8 weeks of heated Bikram yoga reduced brachial-ankle pule wave velocity, an index of AS, and improved quality of life in overweight/obese participants. Similar reductions in AS were indicated by increased carotid arterial compliance in young adults (ages 18-39) following 8 weeks of Bikram yoga. Moreover, a short, intensive yoga program including pranayama and specific postures (90 minutes/day for 15 consecutive days) has been shown to cause favorable changes in body mass index, waist and hip circumference, total cholesterol, postural stability, and handgrip strength (Telles et al., 2014).

A number of components of a yoga practice may be involved in eliciting the physiological and emotional benefits of yoga. Chronic stress has been found to have a profound effect on the central nervous system resulting in an upregulation of sympathetic nervous system activity which can lead to endothelial dysfunction (Ghiadoni et al., 2000). Furthermore, mental stress has been shown to induce transient endothelial dysfunction in healthy individuals (Ghiadoni et al., 2000). Endothelial dysfunction results in decreased bioavailability of nitric oxide with resultant enhanced vascular tone, platelet aggregation, and upregulation of adhesion molecules and is a contributing factor to AS (Ghiadoni et al., 2000).

Yoga postures (asanas) have been shown to reduce stress while improving mood and well-being (Annessi, 2005; Dunn, Trivedi, & O'neal, 2001; Li & Goldsmith, 2012; Matsouka, Kabitsis, Harahousou, & Trigonis, 2005). For example, Alexander, Innes, Selfe, and Brown (2013) reported practicing gentle Iyengar yoga reduced stress and anxiety, improved overall physical function and capacity, enhanced calmness, and enriched the quality of sleep in individuals who were predominantly overweight. Hunter et al. (2016) also demonstrated improvements in quality of life following an 8-week Bikram yoga intervention using the RAND survey which evaluated topics such as role limitations due to emotional problems, emotional-well-being, and social functioning to name a few.

While chronic effects of yoga on mood and vascular function have been demonstrated, it is currently unknown whether these changes are present immediately following a session. The need for prevention strategies against arterial stiffening is urgent given the widespread prevalence of subclinical marker worldwide. Accordingly, the purpose of this exploratory study is to investigate the acute impact of one bout of Vinyasa flow yoga on indices of AS and mood states in healthy adults as finding ways to decrease the amount of people susceptible to AS indirectly makes an impact on people developing CVD.

II. REVIEW OF LITERATURE

Arterial Stiffness and Cardiovascular Disease

AS is measured via carotid-femoral pulse wave velocity (cf-PWV) and augmentation index (AIx) has been established as a strong predictor of future CVD events, mortality, and other complications (Meaume, Benetos, Henry, Rudnichi, & Safar, 2001; Vlachopoulos et al. 2010; van Varik et al., 2017; García-Espinosa et al., 2016; Wang et al., 2015). AS has been associated with the development of hypertension and is a predictor of incident stroke. (Kaess et al., 2012; Mitchell et al., 2010; Pierce, 2017). The mechanisms for arterial stiffening are not fully understood but are thought to involve changes in the extracellular matrix, including degradation of elastin or deposition of collagen (Dao, Essalihi, Bouvet, Moreau, 2005).

A contributing factor to AS is aging, which leads to vascular changes including a thickening and stiffening of the large elastic arteries and alterations in vascular structure and vascular smooth muscle function which can affect vascular tone (Kim et al., 2017). Outcomes associated with AS include increases in systolic blood pressure and a widening of pulse pressure which predisposes older adults to CVD (Kim et al., 2017; Santos-Parker, LaRocca, Seals, 2014). Recent research suggests arterial calcification in the tunica intima or media can reduce a vessel's elasticity and contribute to elevations in blood pressure associated with vascular stiffness (Rattazzi, Bertacco, Puato, 2012). Due to its steadily increasing prevalence (Tsao et al., 2013), treating or preventing aging-related stiffening of the large elastic arteries has emerged as a target for pharmacological and lifestyle interventions/modifications.

Pulse Wave Velocity and Augmentation Index

AS can be measured non-invasively using a few methods: carotid-femoral pulse wave velocity (cf-PWV), carotid arterial compliance, and augmentation index (AIx). Laurent et al. (2006) defined cf-PWV as the reference technique for the noninvasive measurement of AS because of its strong independent links with morbidity and mortality (Mitchell, 2014; Ben-Shlomo et al., 2014; Townsend et al., 2015). Cf-PWV is defined as the velocity of the arterial pulse moving alongside the vessel wall, with a high cf-PWV indicating a stiffer artery (Wang, Mao, Zhao, 2017; Marina, Rosa, Francesco, 2017).

During systole, the ejected volume into the aorta generates a pulse wave called "early systolic peak." The wave is propagated into the periphery and at the level of aortic bifurcations is reflected backward generating a second wave known as "late systolic peak." AS is a cause of premature return of reflected waves in late systole. Thus, it is an important determinant of pulse pressure and has a marked impact on myocardial oxygen consumption and coronary perfusion (Cooper et al., 2016). Aortic PWV is calculated from the return time and the distance traveled by the pulse wave (sternal notch to the pubic symphysis; Cheng et al., 2002; O'Rourke, Gallagher, 1996; Nichols, Singh, 2002; Jatoi et al., 2007; Brewer et al., 2007).

While cf-PWV is considered the gold standard in determining AS, several limitations still exist (Laurent et al., 2006). To begin, it is not convenient to record the carotid and femoral pulse waves simultaneously. Secondly, the distance from the carotid to the femoral artery can be difficult to measure accurately; especially in patients with abdominal obesity (Van Bortel et al., 2002). Lastly, femoral pulse waves cannot be readily and accurately measured in patients with obesity, diabetes, metabolic syndrome, or peripheral arterial disease (Laurent et al., 2006).

Wave reflection, which is convenient to measure due to the need for a single site of pulse measurement (radial pulse), has become of great interest in the estimation of AS, and can be quantified by augmentation index (AIx). Changes in AIx correlate with changes of AS induced by aging, atherosclerosis, or arterial hypertension and have prognostic value for cardiovascular events (Betge, Kretzschmar, Figulla, Lichtenauer, Jung, 2017). Furthermore, central aortic augmentation index (AI_c) has been shown to be an independent predictor of all-cause and cardiovascular mortality in end-stage renal failure patients (London et al., 2001).

AI_c normalized for a heart rate of 75 beats per minute (AI@75) has been demonstrated to be independently associated with severe short- and long-term cardiovascular events in patients undergoing percutaneous coronary interventions (Weber et al., 2005) Yet, AI_c cannot be obtained non-invasively. As a result, research suggests the estimation of aortic pulse wave using transfer functions to provide an alternative method to predict AI_c based on peripheral pulse waves (Chen et al., 1997; Pauca, O'Rourke, Kon, 2001; Gao et al., 2016; Hahn, 2014; Hahn, Reisner, Jaffer, Jaffer, Asada, 2012; Hahn, McCombie, Reisner, Hojman, Asada, 2010; Swamy, Xu, Olivier, Mukkamala, 2009).

The most commonly used device to measure peripheral pulse waves is the SphygmoCor (AtCor Medical, Sydney, Australia), which utilizes applanation tonometry to record the radial artery pulse waveform. The peak and trough of the radial pulse waves are calibrated to the systolic and diastolic blood pressure measured in the brachial artery, and a generalized transfer factor is then used to generate the corresponding aortic arterial waveform (Chen et al, 1997). AIx obtained from applanation tonometry of the radial artery, has attracted interest due to being considered the easiest and quickest of available methods for assessing AS (Takazawa et al., 2007; Takazawa et al., 2012; Hirata, Kojima, Momumura, 2013; Kim et al., 2014). It has been concluded that radial augmentation index (AI_r) serves as an alternative method that provides similar information on central AS as AI_c obtained by a transfer function method (Millasseau, Patel, Redwood, Ritter, Chowienczyk, 2003).

Kohara et al. (2005) suggest the use of AI_r in assessing vascular aging is practical, as AI_r is also reported to be a predictor of premature coronary artery disease in younger males (Fischer-Rasokat, Brenck, Zeiher, Spyridopoulos, 2009). The AI_r technique uses applanation tonometry to obtain wave forms that represent pulse pressure at specific arterial sites (London et al., 2001; Weber et al., 2005; Chen et al., 1997; Pauca et al., 2001). Recordings of pulse pressure are obtained at the first peak (PP1), and second peak (PP2). AI_r is then calculated as the ratio of PP1 to PP2 (Watanabe et al., 2017). In a case of normal arterial compliance, the direct PP1 wave is higher than the early reflected PP2 wave. If the arterial wall is stiffer, a higher amplitude for PP2 will be observed (Vogrin et al., 2017).

Though AI_r has been deemed feasible, the measurement method still has its limitations. AI_r is influenced by several factors including heart rate (HR) and the reflected distance of the pulse wave (Van Bortel et al., 2012). Furthermore, AI_r has been shown not to correlate closely with vascular stiffness as measured by applanation tonometry (SphygmoCor AtCor Medical, Sydney, Australia) in those over the age of 55 (Fantin, Mattocks, Bulpitt, Banya, Rajkumar, 2007).

Exercise Interventions for Arterial Stiffness

Aerobic exercise training has been widely prescribed for reducing the risk of CVD, yet there has not been a gold standard established in prescribing the optimal exercise regimen for attenuating AS (Kim et al., 2017). Research by Seals et al. (2008, 2009) suggests regular aerobic exercise is associated with a suppression of AS progression with aging, while also improving AS in older populations. Moreover, physical exercise seems to be important for minimizing the effects associated with aging on cardiovascular health (Kramer, Bherer, Colcombe, 2004; ten Brinke, Bolandzadeh, Nagamatsu, 2015).

Vaitkevicius et al. (1993) reported aerobically trained individuals had a significantly lower AS than their sedentary counterparts. Cycle ergometer training has demonstrated ability in improving AS via an increase in nitric oxide (NO) bioavailability and reductions in endothelin-1 (ET-1) levels in adults (Kang, Jung, 2010; Maeda et al., 2003). Furthermore, a lower AS results in a longer pressure wave reflection time and lower intensity of the reflected pressure wave, which has favorable effects on central blood pressure (Edwards, Lang, 2005; Otsuki et al., 2007). Naka et al. (2003) also demonstrated acute reductions in peripheral muscular AS with maximal exercise.

Conversely, studies have also demonstrated that chronically resistance-trained males (vigorous resistance training for > 2 years) who had been performing resistance training for over 2 years have stiffer central and peripheral arteries than their sedentary aged-matched peers, which results in increases in central pressure augmentation and widened pulse pressure, which could also increase left ventricular load. (Miyachi, Donato, Yamamoto, 2003; Bertovic, Miller, Fernhall, 1999). Moreover, although resistance exercise can result in positive health benefits and is recommended by professional medical organizations for the prevention of disease, it could possibly have adverse effects on the vasculature and on central hemodynamics.

A need for alternative exercise modes is indicated by the projection of increasing numbers of individuals over the age of 60 and predicted 70% increase in the number of musculoskeletal disorders in the next 15 years (Prince et al., 2015). Alternative bearing exercise modalities must be established to allow implementation in a larger portion of the population in general, especially older adults and those with orthopedic limitations (Prince et al., 2015). Kim et al. (2017) demonstrated improvements in AS in previously sedentary, older adults with 8 weeks of all-extremity non-weight bearing training using a treadmill at a moderate-intensity improved. Hunter et al (2013) suggests "yoga may also present a feasible alternative to traditional exercise in older adults given the low-impact and low joint stress nature of the activity."

Yoga is a combination of flexibility and isometric exercises (Miles et al., 2013), both of which could induce vascular adaptations. Hunter et al. (2013) observed a significant increase in endothelium-dependent vasodilation in middle-aged and older adults after an 8-week Bikram yoga (heated environment) intervention. It has also been demonstrated that 12-week Bikram yoga interventions practiced in thermoneutral and heated environmental conditions enhanced endothelium-dependent vasodilation in middle-aged adults (Hunter, Laosiripisan, Elmenshawy, Tanaka, 2018; Hunter et al., 2016). In the aforementioned study (Hunter et al. 2013), these vascular adaptations were accompanied by improvements in lipid profile, insulin concentrations, and trunk flexibility (Hunter et al. 2013) while Tracy and Hart (2013) also observed increases in isometric deadlift and handgrip strength after 8 weeks of Bikram (heated environment) yoga practice in young adults.

It is reasonable to suggest an increase in endothelial function with yoga could translate into a reduction in AS based upon correlations between these measures in healthy adults (McEniery et al., 2006; Malik, Kondragunta, Kullo, 2008). Patil, Aithala, and Das (2015) demonstrated a 12-week integrated yoga practice consisting of asanas, pranayama, and cyclic meditation significantly reduced cf-PWV and brachial-ankle PWV in elderly men with elevated systolic blood pressure. Moreover, Bikram yoga has also significantly reduced brachial-ankle PWV in overweight and obese adults but not in individuals in the normal weight BMI category (Hunter et al., 2016).

Summary

Of the few studies having revealed positive vascular adaptations with yoga, to date none of have investigated Vinyasa yoga, a style of yoga associated with continuous movement and a higher intensity as measured by metabolic cost. Arterial stiffness has become more prevalent globally with significant associations with CVD morbidity and mortality; prioritizing methods to combat AS is pertinent (Mattace-Raso et al., 2006; Sutton-Tyrell et al., 2005; Willum-Hansen et al., 2006; Mitchel et all., 2010; Laurent et al., 2003; Mitchell et al., 2011; Tsao et al., 2013). Cameron et al. (2013) established AS is a therapeutic target used to assist in the prevention of healthy adults developing CVD. Therefore, the primary aim of the present study is to determine the acute effects of a single Vinyasa flow yoga session on AS in healthy adults.

III. METHODS

Participants

Men and women between the ages of 20 and 75 years were recruited via flyers posted on the Texas State University campus and at yoga studios in the Austin, San Marcos and San Antonio areas. All participants must have had at least three months of yoga experience in order to qualify for the study to ensure the likelihood of proper execution of the postures. Exclusion from this study was based upon the following criteria: i) any known CVD; ii) uncontrolled hypertension; iii) personal history of a stroke; iv) and insulin dependence. This study was approved by the Institutional Review Board (IRB) (5301) at Texas State University.

Procedures

Potential participants were prescreened via health history questionnaires and information about past medical history, current medication use, smoking history, and weekly physical activity was obtained. Written informed consent was obtained from eligible participants prior to testing by research personnel. Testing procedures and study involvement was described by the investigator or a member of the research team. The subject was given time to read the informed consent form and the investigator answered any questions the subject had. Once the subject understood all proceedings, he/she and the investigator both signed the informed consent form and a second copy of the consent form was given to the subject.

Participants reported to the Cardiovascular Physiology Research Laboratory in Jowers for one testing session. In line with standard procedure, participants were asked to fast (water only) for a minimum of 8 hours prior to the session, abstain from exercise 24 hours before participation, and abstain from ingesting of Vitamins C, E, and lipoic acid 3 days prior to the session (Francesomarino, Sciartilli, Valerio, Baldassare, & Gallina, 2009; Papamichael et al., 2005; Plantaniga et al, 2007; Sola et al., 2005). Each session included: review and signing of the informed consent form; 6 seated blood pressure measurements (3 before the yoga session and 3 following the session); and 2 supine blood pressure measurements (1 before and 1 after the yoga session). Seated blood pressure was measured after 5 minutes of rest with the participant seated and their legs uncrossed. Once completed, the following ensued: completion of PANAS (Positive and Negative Affect Schedule) survey (Vera-Villarroel et al., 2017); height and weight measurements; body mass index (BMI) calculation; and augmentation index and pulse wave velocity assessments.

For vascular measures, participants lay down for a minimum of 5 minutes. PWV and AIx, two indices of AS were measured non-invasively using the SphygmoCor CvMS device (SphygmoCor AtCor Medical, Itasca, IL). For AIx, a tonometer was placed over the radial artery in order to obtain continuous blood pressure measurements. For PWV, proximal and distal measurements in millimeters was completed. The proximal measurement was the distance between the carotid artery and the sternal notch and the distal measurement was the distance between the sternal notch and belly button, plus the distance from the umbilicus to the femoral artery. Electrodes were placed on both wrists and the left hip area to obtain heart rate during this measurement. PWV was determined by dividing the distance between artery sites by transit time. Once in place, the tonometer was placed over the carotid artery in order to obtain ten consistent waveforms. The process was completed for the femoral artery as well. The combination of blood pressure waveforms along with the ECG results were analyzed by the device to yield both augmentation index and carotid-femoral PWV.

Once the vascular measurements were completed, the participant was taken to the yoga room located in Jowers, where they completed one hour of an advanced guided Vinyasa flow yoga DVD (Strong Vinyasa Flow Yoga for Strength and Stamina with Jenni Rawlings, 2013). Following the completion of the Vinyasa yoga routine, the participant was escorted back to the laboratory by a member of the research team in order to obtain post-exercise measurements which included all of the procedures described above except height and weight measurements.

Study Design

This study sought to determine the effects of an acute bout of Vinyasa flow yoga on AS and mood. The study consisted of one treatment group. The treatment group was used to measure blood pressure, supine blood pressure, PANAS survey scores, AIx, and lastly PWV. The study consisted of one visit where all pre and post measurements took place, as well as the bout of Vinyasa flow yoga.

Statistical Analysis

Data normality was assessed using the Shapiro-Wilk test. If the data were normally distributed, paired t-tests were used to compare pre- and post-intervention means for our outcome variables. Due to cf-PWV, peripheral AIx, and negative mood affect not being distributed normally, Related-Samples Wilcoxon Signed Rank Tests were used for statistical analysis. Statistical significance was set *a priori* at $P \leq 0.05$ for all tests.

IV. RESULTS

Physical Characteristics

The study population comprised of 30 apparently healthy adults ages 20-75 years old, including 22 women and 8 men (age: 32 ± 14 years, BMI: 22.5 ± 2.3 kg/m^{-2}). Physical characteristics of the participants are presented in Table 1, and the ethnic and racial breakdowns are presented in Tables 2 and 3.

Blood Pressure Measurements

The results of blood pressure measurements following exercise are presented in Table 2. No changes in blood pressure measurements were significant. However, MAP approached a significant decrease. Lastly, a significant increase in HR was observed following the yoga session ($P<0.001$).

Arterial Stiffness Measures

The results of the AS measures are presented in Table 3. After completion of the yoga DVD, significant reductions in AIx and peripheral AIx were observed ($P<0.05$ for all) (Figure 1). No significant changes were observed in AIx@75 ($P=.214$) or cf-PWV ($P=0.628$).

Mood Affect Scores

The results of positive and negative mood affect following exercise are presented in Table 4. No significant changes in positive mood affect were observed; however negative mood affect significantly decreased following the yoga session ($P<0.05$).

V. DISCUSSION

Salient findings from the present investigation were significant reductions in AIx but not cf-PWV following a single bout of Vinyasa yoga. Additionally, a significant decrease in negative affect was observed following the yoga session in the absence of a change in positive affect.

Changes in arterial stiffness

Current findings of reductions in AIx coincide with results from chronic interventions demonstrating reductions in AS measures following 8 weeks (Hunter et al., 2013; Hunter et al., 2016). The lack of change in PWV has been documented previously with no changes in this measure being evident following aerobic exercise (Bruce protocol treadmill test) (Radharkishan, Matthew, Henderson, & Brodie, 2015). In the aforementioned study, measurements were taken 5-10 minutes after exercise where PWV could have had substantial recovery time. In the present investigation, post exercise measurements were recorded on average between 13-20 minutes after the exercise bout, which could have influenced our results as alterations in PWV responses could have been apparent during this short timeframe.

Melo et al. (2016) has shown cf-PWV to transiently increase at 10 minutes following exercise, and then decrease below the baseline at 30 minutes following exercise (Yan et al., 2014). Furthermore, Munir et al. (2008) found PWV unchanged up to an hour after exercise However, a single acute bout of resistance training was associated with a greater cf-PWV and Aix75 (Pierce, Doma, & Leicht, 2018). This suggests that the mode of exercise could influence the degree to which changes in AS become evident post-session. This should also be considered when prescribing exercise as a mixture of endurance and resistance training might be beneficial to offset the increase in PWV that has been associated with some resistance training regimens (Mitchell et al., 2010).

Regarding pulse wave reflection, Pierce et al. (2018) reported a significant reduction in AIx following a bout of aerobic exercise, which is congruent with our findings. Radhakrishnan, Swaminathan, Pereira, Henderson, and Brodie (2017) also recorded a reduction in AIx after acute exercise consisting of an incremental shuttle walk test in people with metabolic syndrome. However, previous studies have had contradictory results with some reporting an increase in AIx (Yoon, Jung, Cheun, Oh, Kim, & Jae, 2010; DeVan, Anton, Cook, Neídre, Cortez-Cooper, & Tanaka, 2005), and others reporting decreases in this measure immediately following an exercise bout (Munir et al., 2008; Sharman, McEniery, Campbell, Coombes, Wilkinson, Cockcroft, 2005).

The reduction in AIx observed post-exercise has been attributed to the effects of vasodilation (Munir et al., 2008) as the redistribution of blood flow during exercise is caused by splanchnic region vasoconstriction in conjunction with cutaneous and muscular arterial vasodilation. In our current study AIx@75 did not change after an acute bout of Vinyasa flow yoga. Similar to our findings, Radhakrishnan et al. (2017) did not observe a significant change in AIx@75 following an incremental shuttle walk test. However, in contrast, Pierce et al. (2018) reported a significant increase in AIx@75 following both acute bouts of aerobic and resistance training sessions. When testing obese and normal-weight individuals using an incremental graded cycling exercise test, Bunsawat et al. (2017) did not observe any changes in AIx@75.

Stoner et al. (2014) states any valid technique utilized to measure physiological variables must be reproducible and argues "adjusting AIx to a HR of 75 beats per minute may be physiologically and statistically inappropriate" adding that there is "uncertainty regarding the normalization of the AIx to heart rate (AIx@75)." Furthermore, Intraclass Correlation Coefficient (ICC) values have been completed at hourly or weekly intervals reported at 0.72-0.90 for AIx, which compared well with cf-PWV ICC values (ICC: 0.92-0.97) (Papaioannou et al., 2007; Wilkinson et al., 1998; Frimodt- Møller, Nielsen, Kamper, Strrangaard, 2007; Papaioannou et al., 2009). However, few trials have reported the reproducibility of HR-corrected AIx@75 values (Papaioannou et al., 2007; Crilly, Coch, Bruce, Clark, & Williams, 2007; Paul, Hewitson, Woodman, & Mangoni, 2009).

Papaioannou et al. (2007) reported both for AIx and AIx@75 and observed improvements in within-day and between-day ICC once normalizing for HR corrected AIx@75. When reporting both AIx and AIx@75, there seem to be conflicting findings. Seven different studies reported significantly improved between-group/condition differences using AIx@75 versus AIx (Avni et al., 2010; Figueroa, Sanchez-Gonzales, Perkins-Veazie, & Arjmandi et al., 2011; Gedikli et al, 2009; Kamran et al, 2009; Kamran et al, 2011; Spence, Kennedy, Belch, Hill, & Khan, 2008; Vlachopoulos et al, 2010). However, and similar to our study where only one between AIx and AIx@75 are significant; two studies reported having no significant differences using AIx but a significant difference using AIx@75 (Martin, Beck, Gurovich, & Braith, 2010; Heilman et al, 2009). Lastly, Shim et al. (2011) reported a decrease in significance when using AIx@75. Due to the discrepancy of conflicting literature that doesn't seem to substantiate

HR corrected AIx@75, Stoner et al. (2014) warns this should warrant careful interpretation of the physiological significance of this method.

The current study showed a significant decline in negative mood affect after only one bout of Vinyasa flow yoga, while positive affect remained unchanged. To our knowledge, this is the first study to assess mood after only one bout of Vinyasa flow yoga. Physical activity has been shown to provide mood, affect, and stress-relief benefits (Carek, Laibstain, & Carek, 2011; Dunn, Trivedi, Kampert, Clark, & Chambliss, 2005; Strohle, 2009. Our findings are similar to those of studies that have shown positive effects on mood as a result of a single yoga session (Eastman-Mueller, Wilson, Jung, Kimura, & Tarrant, 2013; Janakiramaiah et. al, 2000). Similar to our study, Gaskins et. al (2014) observed a significant improvement in mood using the PANAS affect after prescribing Vinyasa yoga to twenty healthy college students 18 years and older for 8 weeks.

The reliability of the PANAS survey has been substantiated as adequate according to Crawford and Henry (2004) as they assessed the PANAS scale using Cronbach's α reporting .89 for positive affect, and .85 for the negative affect questions. Streeter et al. (2010) also observed significant improvements in mood and anxiety in 18 to 45-year-olds who were administered 12 weeks of twice-weekly Iyengar yoga versus walking. Lastly, Eastman-Mueller et al (2013) reported an 8-week iRest (Integrative Restorative) yoga nidra practice improved the mood, anxiety, and stress symptoms among 18-56-year-old, college students with depression.

The present study is not without limitations. Due to participants self-reporting their vitamin supplementation, fasted state, and abstinence from exercise 24 hours prior to the intervention, it is possible the standard protocol was not completely followed by all the participants unbeknownst to the research team. These results may not be the most generalizable due to the fact that the majority of the study demographic was Caucasian, which is an added limitation to the study. The main reason for this could be the minimum experience for study participation was 3 months, which could allude to the fact that the majority of people participating in yoga from the recruited areas were Caucasian as this has been reportedly previously. Finally, measurements were not always taken by the same researchers due to schedules and availability which could potentially have created minor measurement errors and inconsistencies.

The results highlight the efficacy of a single bout of Vinyasa yoga in improving indices of AS and negative mood affect. To our knowledge, this is the first study to investigate the acute effects of Vinyasa flow yoga on AS. The research is encouraging as hatha yoga appears to be versatile in the populations upon which it can make an impact. Furthermore, the knowledge acquired from researching hatha yoga has great clinical relevance as the outcomes of practicing appear to be beneficial for those who participate; while it also maintains the ability to be highly modifiable and cater towards the needs of specific populations. The practical implications include potentially prescribing Vinyasa flow yoga as a method of exercise aimed at attenuating AS and CVD development. Due to our results showing a significant decrease in a measure of arterial stiffness and negative mood affect after only one visit, future research should look to investigate the chronic impact of Vinyasa flow yoga on indices of AS in healthy and at-riskpopulations. Further research is needed to see if chronic adherence to a Vinyasa flow yoga could also yield changes in pulse wave velocity as no acute changes were observed in the present investigation. There is a possibility that adhering to a chronic intervention of Vinyasa flow yoga could yield greater results that would prove to be beneficial to the participants.

This study is both novel and exploratory as there have been no studies completed investigating the acute or chronic effects of Vinyasa flow yoga on indices of AS. In conclusion, the data show that one bout of Vinyasa yoga is useful in improving central and peripheral AS measures and provides insight into the potential effects of yoga in mediating CVD risk. This study carries great clinical importance as finding ways to attenuate AS within the general population will also indirectly impact the amount of people susceptible to developing a type of CVD, the leading cause of death in the United States.

Table 1
Physical Characteristics of the Participants

Male/Female	8/22
Age (yr)	32 ± 14
Height (cm)	169.8 ± 7.8
Body Mass (kg)	65 ± 9.6
Body Mass Index (kg/m^{2})	22.5 ± 2.3

Data are presented as means ± SD

Table 2
Breakdown of Ethnicity in Study Population

Ethnicity	n
Non-Hispanic	24
Hispanic	6

Table 3
Breakdown of Race in Study Population

Race	n
Asian	1
Black	5
White	21

Table 4
Changes in Cardiovascular and Hemodynamic Characteristics

	Before	After	P
Heart Rate (BPM)	62 ± 12	66 ± 12	.001**
Systolic BP (mmHg)	117 ± 9	116 ± 11	.185
Diastolic BP (mmHg)	75 ± 8	72 ± 7	.150
Mean BP (mmHg)	89 ± 7	87 ± 8	.093
Pulse Pressure (mmHg)	42 ± 9	43 ± 8	.902

Data are presented as ± SD
**P <0.001
BP= blood pressure

Table 5
Changes in Arterial Stiffness

	Before	After
cf-PWV (m/s)	5 ± 2	5 ± 1
Augmentation Index %	12 ± 17	5 ± 14**
Augmentation Index@75 %	4 ± 19	2 ± 15

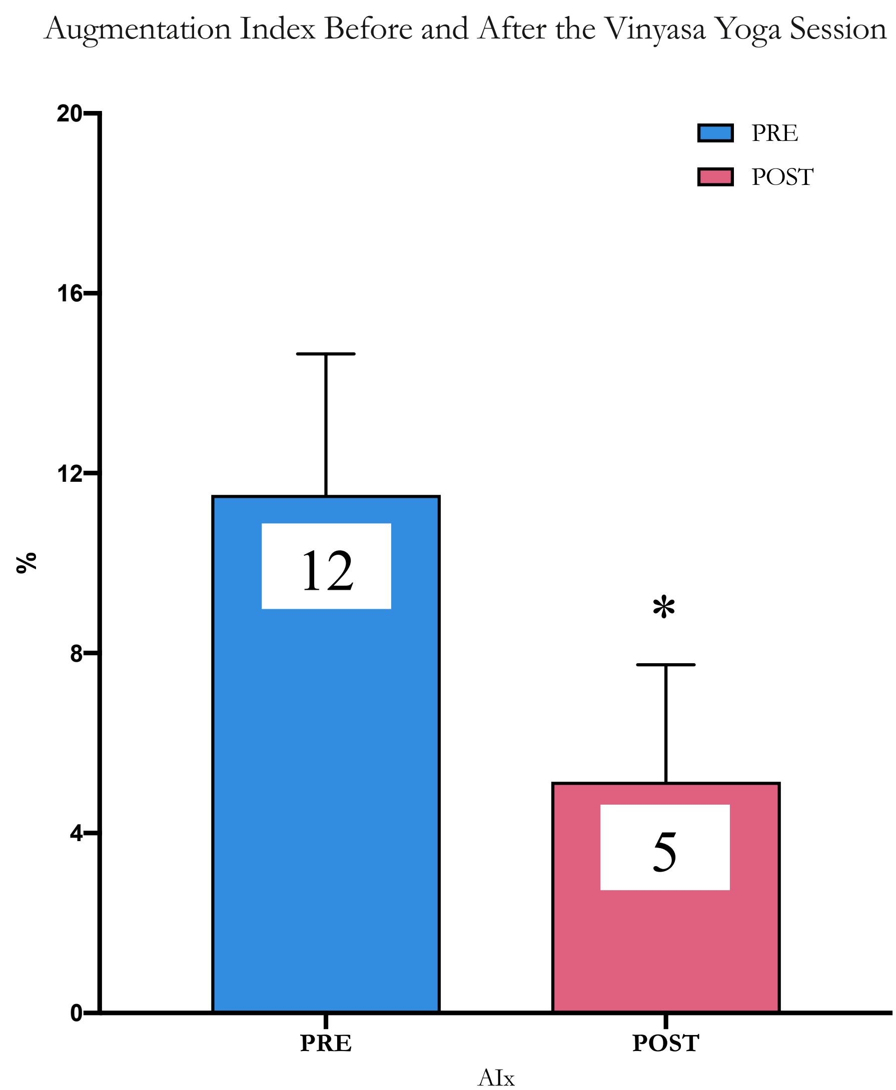
Data are presented as means ± SD
* P <0.05
** P < 0.01
cf-PWV=carotid femoral pulse wave velocity

Table 6
Changes in Positive and Negative Mood

	Before	After
Positive Mood Affect	34 ± 8	35 ± 8
Negative Mood Affect	12 ± 2	11 ± 1*

Data are presented as means ± SD
*P <0.05

Figure 1



Data are presented as means ± SE.
*P < 0.05

APPENDIX SECTION

1. PANAS survey

52 Therapist's Guide to Positive Psychological Interventions

Worksheet 3.1 The Positive and Negative Affect Schedule (PANAS; Watson et al., 1988)

PANAS Questionnaire

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word. **Indicate to what extent you feel this way right now, that is, at the present moment *OR* indicate the extent you have felt this way over the past week (circle the instructions you followed when taking this measure)**

1	2	3	4	5
Very Slightly or Not at All	A Little	Moderately	Quite a Bit	Extremely

___________ 1. Interested	___________ 11. Irritable
___________ 2. Distressed	___________ 12. Alert
___________ 3. Excited	___________ 13. Ashamed
___________ 4. Upset	___________ 14. Inspired
___________ 5. Strong	___________ 15. Nervous
___________ 6. Guilty	___________ 16. Determined
___________ 7. Scared	___________ 17. Attentive
___________ 8. Hostile	___________ 18. Jittery
___________ 9. Enthusiastic	___________ 19. Active
___________ 10. Proud	___________ 20. Afraid

Scoring Instructions:

Positive Affect Score: Add the scores on items 1, 3, 5, 9, 10, 12, 14, 16, 17, and 19. Scores can range from 10 – 50, with higher scores representing higher levels of positive affect. Mean Scores: Momentary = 29.7 (*SD* = 7.9); Weekly = 33.3 (*SD = 7.2)*

Negative Affect Score: Add the scores on items 2, 4, 6, 7, 8, 11, 13, 15, 18, and 20. Scores can range from 10 – 50, with lower scores representing lower levels of negative affect. Mean Score: Momentary = 14.8 (*SD* = 5.4); Weekly = 17.4 (*SD* = 6.2)

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