THE EFFECTS OF PHYSICAL ACTIVITY AND YOGA ON CAROTID ARTERY STIFFNESS

By

COURTNEY DUREN

(Under the Direction of Kevin McCully)

ABSTRACT

Carotid artery stiffness is an accepted marker of cardiovascular disease. Aerobic activity is associated with reduced stiffness. Yoga's effect on stiffness is unknown. The hypotheses were that stiffness wouldn't differ between yoga and aerobic subjects but yoga subjects would have lower stiffness than sedentary subjects, stiffness measures are reliable, and ECG is a valid measure of pulse wave velocity (PWV). Stiffness was measured by distensibility (DC) and PWV. Physical activity was determined by a questionnaire. The yoga and aerobic group had no difference in stiffness (DC, $p = 0.26$ and PWV, $p = 0.20$). The yoga group had lower stiffness than sedentary subjects (DC and PWV, $p < 0.001$). The yoga and aerobic group had similar physical activity levels. Physical activity was the best predictor of stiffness. The yoga group was more physically active than sedentary subjects. Stiffness measures were reliable (CV=2.5%) and similar left to right (CV=2.2%). PWV (ECG and carotid-femoral) correlated highly R^2=0.93. It was concluded that stiffness was related to physical activity, and an independent effect of yoga on stiffness couldn't be detected. Stiffness measures were reproducible and left and right sides were consistent with each other.

INDEX WORDS: carotid artery stiffness, pulse wave velocity, electrocardiogram

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COURTNEY DUREN

B.S., The University of South Carolina, 2004

A Thesis submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

ATHENS, GEORGIA

2006

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By

Courtney Duren

Major Professor: Kevin McCully
Committee: Kirk Cureton
Elaine Cress

Electronic Version Approved:

Maureen Grasso
Dean of Graduate School
The University of Georgia
August 2006

DEDICATION

In memory of Carrie Anna Duren (March 16, 1923-May 4, 1995).

"A grandma is warm hugs and sweet memories. She remembers all of your accomplishments and forgets all of your mistakes. She is someone who you can tell your secrets and worries to, and she hopes and prays all of your dreams will come true. She always loves you, no matter what. She can see past temper tantrums and bad moods, and makes it clear that they don't affect how precious you are to her. She is an encouraging word and a tender touch. She is full of proud smiles. She is the one person in the world who loves you with all of her heart, who remembers the child you were and cherishes the person you have become." Barbara Cage

Grandma, you will always be in my heart and mind, and I appreciate all of the love and support you gave me when you were alive. Rest in Peace.

ACKNOWLEGEMENTS

In no particular order I would like to thank the following people:

I would like to thank all the participants who volunteered there time for the study because if it were not for them this study would not be possible.

Next, I would like to thank my committee members Dr. Kevin McCully, Dr. Elaine Cress, and Dr. Kirk Cureton for all of there input, encouragement, and support and for keeping me on track during this study.

I owe a huge thanks to Tucker Bruno who helped with the participants and with data analysis during the study and a gigantic thanks to my sister and fellow graduate student Kimberly Duren who took time out of her busy schedule to help me when equipment was not working and when I needed assistance.

Last, but not least, I'd like to thank my mother and youngest sister for loving, and believing in me and supporting me every step of the way.

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CHAPTER ONE

Introduction

Cardiovascular diseases are the leading cause of death in America (27, 36). Deaths caused by cardiovascular disease continue to increase and because the occurrence of this disease is so high, considerable efforts are being spent to understand and prevent the onset of these diseases. Several risk factors are associated with CVD: obesity, hypertension, high cholesterol, smoking, physical inactivity, age, and central arterial stiffness (15, 27, 36).

One risk factor for cardiovascular disease that has received recent attention is central arterial stiffness. Central arterial stiffness can be measured in a number of different ways, including direct measurements of carotid arterial distensibility(38) and indirectly by measuring the speed at which the arterial pressure wave travels in the central arteries (pulse wave velocity, PWV). Several studies that have investigated central artery stiffness at the carotid artery have found that there is an age-related increase in stiffness (36, 38). Carotid artery stiffness can be measured easily because it is a superficial artery in the neck.

Carotid artery distensibility is measured using ultrasound to determine changes in arterial diameter across the cardiac cycle. The greater the change in arterial diameter for a given change in blood pressure, the more distensible and healthier the artery is supposed to be. This measurement has the advantage of being non-invasive, although precise measurements of arterial diameter are required, and blood pressure measurements in the arm must be used in place of pressure measurements in the neck.

Pulse wave velocity in another measurement of central arterial distensibility. Pulse wave velocity measures the distance and time it takes blood pressure to travel two points in the body. Pulse wave velocity can be measured by ECG where you measure the time it takes pressure to travel from the heart to the femoral artery or by carotid-femoral tonometry where you measure the time it takes for pressure to travel from the carotid to the femoral artery (33). Several studies have shown that B-mode ultrasound and pulse wave velocity are reliable measures of central artery stiffness, (16). PWV is also noninvasive and relatively simple to obtain. However, tonometry requires specialized equipment and a skilled operator.

One factor thought to reduce central artery stiffness and benefit cardiovascular health is physical activity. People who regularly participate in some form of aerobic exercise have lower central artery stiffness than their sedentary counterparts and participating in regular aerobic exercise can reduce the age related increase in arterial stiffness (30). Not all forms of physical activity have been shown to have a beneficial effect on arterial stiffness. Unlike aerobic exercises, people who regularly participate in high intensity resistance training have higher central artery stiffness than their sedentary counterparts (25).

One form of physical activity that has not received much attention concerning central artery stiffness and cardiovascular disease is yoga. Yoga is thought to have several beneficial physiological and cardiovascular effects (1). Several styles of yoga exist and each yoga style involves exercising in different postures and at different intensities (10). People who perform moderate intensity yoga have been shown to have better cardiovascular functioning than sedentary people (9). Because of these findings, it is possible that yoga will have similar effects on arterial stiffness as aerobic exercise. People experienced at performing yoga normally perform an inversion postures, which involves holding a position where the head is below the body. Inversion has been shown to increase blood flow to the carotid artery, reduce resting heart rate, and reduce pulse pressure, which suggest that it may cause the same decrease in central arterial stiffness as aerobic exercise (13, 17).

Examining the reliability of arterial stiffness measures can provide helpful information when studying the risk for cardiovascular disease. Measurements that are less reliable will require multiple measurements and larger sample sizes in order for the results to be interpreted. In addition, cardiovascular disease is not uniformly distributed when present, so that it is not clear if the left and right carotid arteries should have the same value in the same subject.

Study Aims

The aims of this study were to:

1. To determine central artery stiffness in middle-aged subjects who regularly practice yoga that includes inversion postures.
2. To determine if measuring central artery stiffness using ultrasound and pulse wave velocity are reliable.
3. To determine if there are systematic differences between left and right carotid artery stiffness.
4. To determine if there are systematic differences between PWV (ECG) and PWV (carotid-femoral tonometry).

Hypotheses

1. People who regularly practice yoga that includes inversion postures have lower central artery stiffness than their sedentary counterparts.
2. People who regularly participate in yoga that include inversion postures have levels of central arterial stiffness similar to people who are moderately physically active.
3. There will be less than a 10% coefficient of variation when central artery stiffness is measured on two separate occasions when the participant is at rest.
4. There is no difference between the right and left carotid artery.
5. PWV (ECG) will be highly correlated with PWV (carotid-femoral tonometry), which is the gold standard.

Definition of terms*:*

1. Carotid Artery Stiffness: hardness of the superficial arteries in the neck (carotid arteries).
2. Pulse wave velocity: time it takes for pressure to pass through the arteries that with each contraction of the left ventricle of the heart.
3. electrocardiogram: graphic of the electrical voltage of the heart

Significance of Study

The present study will evaluate hatha yoga participants that practice inversion postures, a population of people that are not well studied in terms of cardiovascular benefits and carotid artery stiffness. Yoga has been studied in terms of cardiovascular benefits such as blood pressure, but no studies have examined arterial stiffness in those practicing yoga. Given the recent popularity of yoga, a better understanding of the cardiovascular effects is needed to understand its potential role in reducing the risk for cardiovascular disease.

Another significant aspect of the study is that it will assess the reliability of measuring carotid artery stiffness day one to day two compare measures from the left right sides. If the measure is reliable, it would be easier to use one measurement per subject rather than having to measure on multiple days and on both sides. Several studies have only measured the right carotid artery as their measure of arterial stiffness. As people, age arteries become stiffer and the stiffness may occur at different rates in the left and right carotid arteries. This study will determine if this is the case in healthy middle-aged people. Pulse wave velocity (ECG) is limited because of the use of a constant isovolumetric contraction time. It is thought that this may lead to an inaccurate measure of pulse wave velocity using this technique. This study is designed to determine if this is indeed true.

CHAPTER TWO

Review of Related Literature

Cardiovascular Disease

Cardiovascular diseases are the leading cause of death in the United States and is caused by dysfunctional conditions of the heart, arteries, and veins that supply oxygen to vital life sustaining areas of the body (20). Cardiovascular disease represents more than thirty percent of all deaths in the United States. Over the years several risk factors have been studied in order to determine prevention and treatment of cardiovascular disease. Some of these risk factors include heredity, gender, age, smoking, obesity, high cholesterol, high blood sugar levels, central arterial stiffness, and physical inactivity (32).

Arterial Stiffness

One risk factor associated with cardiovascular disease is stiffness of the central arteries. The central arteries are extremely important in taking blood to the heart and stiffness in these arteries cause less expansion and recoil during cardiac contraction and relaxation (34). The arterial system is responsible for preventing high blood pressure in the arteries. If an artery is compliant it will easily be able to expand during systole making it easier for blood and oxygen to circulate through the artery. If the artery stiffens, blood flow becomes restricted and arterial pressure begins to increase (34). Stroke, arteriosclerosis, and left ventricular hypertrophy may be caused by stiff arteries (35). Carotid arteries and the aorta are considered the main central arteries and several research concerning central artery stiffness focuses on the carotid arteries because it is easy to measure and it correlates well with cardiovascular disease (23). Stiffening of the central arteries is thought to play a big role in several cardiovascular diseases (38).

The most important mechanical changes that may lead to stiffness of the arteries are decrease in arterial wall elastin and increase arterial collagen (23). When a person becomes older, their arterial walls begin to thicken, plaque begins to build up, and structural changes begins to occur within the elastic properties of the arteries (23, 34). Studies that have examined carotid artery stiffness have found that increased age and decreased levels of physical activity cause an increase in stiffness (31, 34).

Arterial stiffness and Age

Aging is the main determinant of central artery stiffness (34). Several cross sectional studies have shown an increase in central stiffness with an increase in age (26, 34). Tanaka et al. (34) used ultrasound and tonometically obtained pressure observed a 40% decrease in carotid artery compliance between the age of 25 and 75.

Aerobic Exercise and Arterial Stiffness

Several studies have explored the effect of different types of exercise on carotid artery stiffness. When examining the effects of aerobic exercise on stiffness, studies have found that people who regularly participate in moderate intensity aerobic exercise have lower carotid artery stiffness than their sedentary counterparts (12, 26, 34). Studies have also found that engaging in aerobic training can decrease carotid artery stiffness (34). The reason that aerobic exercise is thought to decrease stiffness is because arterial compliance is mainly determined by the intrinsic elastic properties of an artery. An artery wall is made up of collagen, elastin, and vascular tone affected by the vascular smooth muscle. Regular participation in aerobic exercises is thought to cause changes in the elastin-collagen composition of the arterial wall over time. It is also thought that during an aerobic exercise session, pulse pressure and mechanical distension are increased causing collagen fibers to stretch and arterial compliance to increase (34). Not all forms of physical activity have been found to have a beneficial affect on carotid artery stiffness.

Resistance Exercise and Arterial Stiffness

Unlike aerobic exercises, resistance training has been shown to increase carotid artery stiffness. Several studies have shown that people who regularly participate in resistance training have higher central artery stiffness than people who are sedentary or who participate in aerobic exercise (4, 24, 25). The reason behind stiffness caused by resistance training is unclear, but it is speculated that it may be due to the increase in arterial blood pressure during resistance exercise (24). During resistance training, arterial blood pressure can become as high as 320 systolic and 250 mmHg diastolic (19). This high pressure may alter the arterial structure or arterial load-bearing properties of collagen or elastin of an artery and that could lead to stiffness (24, 25).

Yoga and Arterial Stiffness

One form of activity that has not received much attention in respect to central artery stiffness is hatha yoga. Yoga is a very popular form of physical activity all over the world. Several forms and intensities of yoga exist. Yoga styles range from Ananda yoga, which is a low intensity style that involves the use of silent affirmations while in different postures to Ashtanga yoga, which is a high intensity style that involves moving through a series of flows and jumping from one posture to another to build strength, flexibility and stamina to power yoga, which is a high intensity style that involves moving through different yoga postures without resting (8). Yoga styles are based on Indian culture and some have been shown to have beneficial physiological, psychological, and cardiovascular effects (7). Several studies have shown that long-term moderate intensity yoga practice reduces systolic blood pressure, diastolic blood pressure, pulse rate, heart rate, and left ventricular end-diastolic volume (1, 2, 6, 9, 21). Bharshankar et al. (1) did a study looking at the effect of different yoga posture exercises, breathing techniques, and meditation on the cardiovascular variables in people over 40 years of age. The study showed that compared with people who did not perform yoga; the yoga group had lower resting heart rate, systolic blood pressure, and diastolic blood pressure than the control group.

Inversion Yoga Posture and Arterial Stiffness

Postures that are very common in most styles of yoga are inversion postures. People who are experienced in yoga normally perform postures with some form of inversion. Inversion postures involve a position where the head is below the body where the subject after lying supine raises his trunk and legs straight above his head with his neck, shoulder, and arm muscles supporting the body weight. There are two common forms of inversion postures: shirshasana (head stand)-head down body up posture where arms support the body weight and sarvangasana (shoulder stand)- head down body up posture where the shoulders and arms support the body weight. Studies involving inversion postures have shown that it increases venous return to the heart (13). Practicing of inversion postures have also been shown to increase blood flow to the carotid artery, reduce systolic blood pressure, and reduce resting heart rate (17, 37). Konar et al did a study looking a the effects of inversion posture on cardiovascular variables and found that two weeks of exercises in the inversion posture caused a significant reduction in resting heart rate and left ventricular end diastolic volume at rest (13). The reason that inversion postures is thought to have an influence on the carotid arteries is because this posture uses gravity to cause the pressure of cerebrospinal fluids to push on blood vessels bringing more blood to the heart, brain and central arteries which leads to a reduction in sympathetic vasomotor control and an increase in venous return (17, 37). However, some studies have shown that while in an inversion posture position there is an increases blood pressure (3, 37). One study showed that systolic and diastolic blood pressure were 7% and 15% higher during head down posture than supine rest suggesting that gravity causes pressure to increase in the blood vessels of the head and neck when a person is in the head down posture (3).

Measurements of arterial stiffness

Several noninvasive methods have been developed to measure arterial stiffness. One of the most common ways to measure arterial stiffness is by directly measuring arterial diameter and pressure. Arterial diameter and pressure can be taken using an ultrasound machine (16). Another noninvasive way to measure arterial stiffness is pulse wave velocity. Pulse wave velocity is one of the most widely used ways to evaluate arterial stiffness and involves measuring the distance and time it takes pressure to travel a certain distance. Measuring pulse wave velocity provides an indication of arterial stiffness in the vascular bed.

Carotid Artery Ultrasound

Ultrasound is a popular form of measuring carotid artery stiffness. Ultrasound works by the principal that when sound waves are emitted through the body they collect the reflected sound waves producing an image of the body. The sound wave travels through different tissues of the body sometimes reflecting back towards the ultrasound transducer. These echoes can be used to produce an image. Images are formed when detecting echoes are reflected from two tissue types with different acoustic values. The greater the difference in acoustic values between the two tissue types the greater the echo intensity of the reflected sound wave. The echo intensity received back from each interface can be reconstructed and displayed. The echo intensity can then be mapped into pixel brightness and viewed in a monitor. The conversion between echo intensity and pixel intensity produces a grey scale image (5).

Pulse Wave Velocity

Another noninvasive marker of central arterial stiffness is central pulse wave velocity. Pulse wave velocity is how quick blood pressure pulses travels from one point to the next in the body. It can be measured by electrocardiogram or by application tonometry. PWV by ECG involves measuring the time elapsed from the peak of the "R" wave to the beginning of the up stroke of the pulse pressure Wave. Electrocardiogram assumes blood is ejected from the ventricle into the aorta 50 milliseconds after the peak of the "R" wave (isovolumetric contraction time) (14). ECG used to measure PWV is easy and very convenient. One problem concerning this method is that it assumes that isovolumetric contraction time is the same for everyone, which may not be true.

Recently, carotid tonometry has fast become the standard for measuring pulse wave velocity. Tonometry uses pressure waveforms at the carotid and femoral arteries to assess the time it takes for blood to travel that distance by allowing pressure waveforms and amplitude to be obtained from the left and right carotid artery with a pencil-type probe incorporating a high-fidelity strain gauge transducer and from the right and left femoral arteries using a blood pressure cuff inflated to 60mmHg. This instrument is based on application tonometry to measure intraocular pressure. Tonometry on an exposed artery has been shown to record a waveform identical to that recorded intra-arterially and registers a pressure wave that does not differ from that of an intra-arterially recorded wave. The measured pressure waveform will consist of a forward wave and a reflected wave that is returning from a peripheral site. The reflected wave will superimpose on the incident wave so that the pulse and systolic pressure are increased (34). Carotid tonometry is now the gold standard of measuring central artery stiffness causing ECG to be used less and less. Using ECG is easier and more convenient than carotid tonometry. Few studies have examined how well ECG PWV correlates with carotid tonometry PWV.

Baecke Questionnaire of Physical Activity

Measuring physical activity is important in the field of arterial stiffness. Questionnaires are very convenient when it comes to measuring physical activity. The Baecke Physical Activity Questionnaire has been shown to be very reliable when measuring physical activity. In this questionnaire, participants respond to 16 questions concerning their work activity, sports activity and their leisure activity. A cumulative score is calculated by adding the three component scores. It is assumed that the higher the score on the questionnaire, the more active the subject (28).

CHAPTER THREE

The Effects of Physical Activity and Yoga On Carotid Artery Stiffness

[1]

[1] Duren, C.M, McCully K., Cress, E. To be submitted to the *European Journal of Applied Physiology*

ABSTRACT

Carotid artery stiffness is an accepted marker of cardiovascular disease. Aerobic activity is associated with reduced stiffness. Yoga's effect on stiffness is unknown. The hypotheses were that stiffness wouldn't differ between yoga and aerobic subjects but yoga subjects would have lower stiffness than sedentary subjects, stiffness measures are reliable, and ECG is a valid measure of pulse wave velocity (PWV). Stiffness was measured by distensibility (DC) and PWV. Physical activity was determined by questionnaire. Yoga and aerobic subjects had no difference in stiffness (DC, $p = 0.26$ and PWV, $p = 0.20$). Yoga subjects had lower stiffness than sedentary subjects (DC and PWV, $p < 0.001$). Yoga and aerobic subjects had similar physical activity levels. Physical activity was the best predictor of stiffness. Yoga subjects were more physically active than sedentary subjects. Stiffness measures were reliable (CV=2.5%) and similar left to right (CV=2.2%). PWV (ECG and carotid-femoral) correlated highly R^2=0.93. It was concluded that stiffness was related to physical activity, and an independent effect of yoga on stiffness couldn't be detected. Stiffness measures were reproducible and left and right sides were consistent with each other.

INDEX WORDS: carotid artery stiffness, pulse wave velocity, electrocardiogram

Introduction

Cardiovascular disease is a major cause of death in the United States. Arterial stiffness particularly in the central arteries has been implicated in the progression of cardiovascular disease (38). Central arterial stiffness also has been shown to increase with age. The increase in arterial stiffness has been shown to be related to thickening of the intimae layer, a decrease in elastin fiber and an increase in collagen content (34).

Aerobic exercise has been shown to reduce the age-related increase in arterial stiffness (34). Strenuous resistance exercise has been show to increase arterial stiffness, however, perhaps due to the large increase in blood pressure that occurs with resistance training. While a number of studies have shown that practicing yoga reduces blood pressure (1, 2, 6), it is not clear what effect Hatha yoga would have on central artery stiffness. Regular Hatha yoga practice often involves the practice of inversion yoga postures (13, 21). Considering the evidence that postures where the head is below the torso has been shown to increase blood flow to the carotid arteries (3), it may be implied that this posture may also contribute to decrease in stiffness in the carotid arteries.

Previous studies have shown that measuring central arterial stiffness either by using ultrasound (16) to measure changes in arterial diameter together with pressure, or by measuring the pulse wave velocity (PWV) are reproducible to within 10%. However, ultrasound measurements are often performed on one carotid artery, and cardiovascular disease is known to be asymmetrical in its presentation. PWV measurements have been performed using either ECG of the heart or carotid-femoral tonometry to time the pressure wave (34). ECG measurements have the disadvantage of assuming a constant isovolumetric contraction time while tonometry measurements require a skilled operator.

Thus, it is important to determine the reliability of measurements of central artery stiffness, and in particular to compare the left and right carotid arteries and to compare the different measurement methods.

The purpose of this study was to measure central artery stiffness in healthy middle-aged adults who were sedentary or moderately active, or who performed yoga. Central artery stiffness was measured with ultrasound of the carotid artery, and with PWV (ECG and carotid-femoral tonometry). Measurements were made on two days, and in both the left and right carotid artery. We hypothesized that the regular practice of yoga with inversion postures would be associated with reduced arterial stiffness, that the measures of arterial stiffness would be reproducible, and that there would be a good agreement between the different measurements.

Methods

Subjects

A total of 27 healthy men and women were studied. Two volunteers were excluded from the study. All participants were between the ages of 40-65 years and were placed into one of three groups. Sedentary subjects performed < 1 bout of vigorous activity a week in the previous year (N=9); Yoga subjects performed yoga, including some form of inversion yoga at least 2 days a week in the previous year (N=8) and aerobic subjects performed some form of aerobic exercise (walking, cycling, aerobics) ≥ 3 days a week, ≥ 30 minutes a day in the last year (N=10). The Baecke Habitual Physical Activity Questionnaire was used to determine physical activity levels (28).

The participant's health was determined by a health questionnaire. All subjects were normotensive (<140/90 mmHg), nonobese, and free of chronic diseases. Subjects were excluded from the study if they were hypertensive, smoked, took any major medication, or had any form of cardiovascular disease. Gross differences in nutritional habits were identified using four simple nutrition questions.

All subjects gave their written informed consent to participate. All procedures were reviewed and approved by the Internal Review Board at the University of Georgia.

Testing procedures

Before the participants were tested, they abstained from caffeine and any form of exercise at least 2 hours before the testing session. All participants but one reported twice to the lab for testing. On the first visit the subjects filled out the Baecke Questionnaire of Habitual Physical Activity to assess activity levels and answered questions on yoga and nutrition. Height and weight were measured and body mass index was calculated. The participants (N=26) were tested on two separate days at similar times for both days.

Carotid Artery Stiffness

After the subject rested in the supine position for 10 minutes, testing was performed under quiet resting conditions while in the supine position. The right carotid artery was imaged 3-5 cm proximal to the bulb using B-mode ultrasound with a 9mHz linear probe (General Electric LOGIQ 400CL). All movies were taken for 10 seconds while the participant was holding his/her breath. Brachial artery blood pressure was taken at the right brachial artery by an automatic blood pressure machine (Dynamap) immediately before and after ultrasound images were taken and used to determine carotid artery stiffness. After the right carotid and brachial artery were assessed, the same measurements were taken on the left carotid and brachial arteries. B mode images were saved as digital movies and analyzed using semi-automated wall detection software (29). The same investigator performed all image analyses. Time points that correlated with maximal systolic expansion and diastolic relaxation of the carotid artery were selected along with systolic and diastolic blood pressure by the automated blood pressure machine. To characterize carotid stiffness, distensibility coefficient was calculated. Distensibility coefficient was calculated as $DC = (2\Delta d/D)/\Delta p$ where Δp is the pulse pressure, Δd is the difference between systolic and diastolic diameter and D is the end systolic diameter. A total of 4 ultrasound movies were taken each day (2 from the left and 2 from the right carotid arteries). An average of the four measurements was used to determine distensibility for that day. Distensibility coefficient provides an index of arterial stiffness adjusted for diameter differences seen between men and women.

Pulse Wave Velocity

To calculate PWV (carotid-femoral tonometry and ECG) were used. For tonometry, a force transducer (Grass, Inc) with a 2 mm diameter tip was placed on the carotid artery. ECG measurements were collected with three electrodes on the chest to measure the ‘R’ wave. The R wave represents the contraction of the myocardium of the ventricles. A blood pressure cuff was placed proximally on the thigh and inflated to 60 mmHg. The waveforms from the three sites were collected simultaneously into a Biopac data acquisition system with Acknowledge Software set to collect at 200 samples per second.

PWV =distance/time

For tonometry, the distance between the force transducer on the carotid artery and the cuff on the femoral artery was measured using a tape measure. Time was calculated from the foot of the pressure wave at the first point (carotid artery) to the foot of the pressure wave as it arrived at the next point (femoral artery) over five cardiac cycles. The distance in meters was divided by the time to determine PWV by tonometry.

For ECG, the distance from the approximate location of the heart to the femoral artery was taken using a tape measure and the delay duration (time it takes for blood to travel the distance minus 0.05 seconds) was used taken using the R wave and the waveform produced by the femoral (thigh) cuff. PWV taken by carotid tonometry and ECG and the waveforms each method produced can be seen in the Figure 1.

Body composition

Body composition was assessed using body mass index and waist to hip ratio. Body mass index was calculated by weight in kilograms divided by height in meters squared. Weight was assessed using a digital weight scale and height was assessed using a height scale. Waist to hip ratio was taken using a tape measure and measuring waist circumference and dividing it by hip circumference.

Physical Activity Questionnaire

To assess physical activity for each group, the Baecke Questionnaire of Habitual Physical Activity was used (28). The questionnaire consists of 3 sections: work, sport, and non-sport leisure activity. Most of the questionnaire was scored on a 5-point scale, with descriptors ranging from never to sometimes or very often. Three additional questions required reporting the type of sporting (exercise) activity and both the number of hours per week and the number of months per year in which they participated in that activity. The participants were also asked if they did any yoga, if they answered yes, then they were asked if they did any inversion yoga postures and if so, how many days a week they performed any form of inversion yoga posture.

To determine if a participant practiced Hatha yoga every participant was verbally asked if they performed yoga, if so if they performed any inversion postures, how many days a week do they perform those inversion postures and how long have they been performing those inversion postures.

Nutrition

The participants answered four nutritional questions. The first question was is if they eat meat and if so how much meat do they eat in a week. The second question was if they eat fried foods and if so how often do they eat it in one week. The third question was if they skinned their chicken, and the fourth question was how often they ate vegetables. The questionnaire was scored on a scale of 0 to 1.

Reproducibility (Visit 1 and 2)

To determine reproducibility for heart rate and blood pressure in the brachial artery, blood pressure and heart rate were taken at the right and left brachial arteries by an automatic blood pressure machine (Dynamap) immediately before and after ultrasound images were taken. The average of the before and after measurements were used to determine blood pressure and heart rate used with each ultrasound diameter measurement. A total of 4 ultrasound measurements were taken each day (2 from the left and 2 from the right carotid arteries) and the average of all four measurements were used to determine day 1 heart rate and blood pressure.

Systolic and diastolic diameters for each measurement were determined by averaging values for five heart beats during the 10 seconds of data collection. The diameter change was the average difference between systolic and diastolic diameter.

Reproducibility of pulse wave velocity for visit one was determined by taking the average pulse wave velocity from the left and right sides. Pulse wave velocity was calculated as described in the pulse wave velocity section. Pressure waveforms from the ECG, force transducer, and femoral cuff were recorded for two minute. The biopac took continuous waveform measurements for those two minutes and the participant was asked to hold his breath twice during those ten minutes. Each breath hold lasted 10 seconds and the time each breath hold began was recorded. Time from the foot of the pressure wave at the carotid artery (carotid tonometry) or R wave (ECG) to the foot of the pressure wave at the femoral artery was measured over five cardiac cycles and the average of those cardiac cycles were used to determine time from one breath hold. The same procedure was done for the second breath hold and an average time of the two breath holds was divided by distance to determine pulse wave velocity for the side. The same procedures were done for both sides to determine visit one pulse wave velocity. The same time points were used for ECG and carotid tonometry.

On the second visit, measurements were taken the same way and compared to the measurements on the first day to see if there was a systematic difference between the measurements between visits.

Comparison (left versus right)

For each measurement the same thing was done. Measurements were taken as described above. Two images were taken on the left carotid artery each day and the average of the two days were used to determine heart rate and blood pressure of the left side. The same procedures were done on the right side and the two sides were evaluated to see if there was a systematic difference.

Statistical Analysis

The differences between the three groups with respect to descriptive characteristics were assessed using a one-way ANOVA using Bonferoni comparison (yoga, moderately active, and sedentary by right and left carotid artery stiffness). The influence of physical activity on carotid arterial stiffness was assessed using one-way ANOVA. All models included all three groups and both carotid artery measurements. The outcome variable was central arterial stiffness and data was reported as means ± standard errors. Differences were significant if $P < 0.05$.

Repeated measures ANOVA was used to determine the significance of difference between visit 1 and visit 2. A paired t-test was used to assess the significance of difference between the left and right carotid arteries. Coefficient of variation (CV = (S.D./μ)*100) was calculated between the left and right carotid arteries and between the two visits. A CV of less than 10% was used to determine the reproducibility between visit one and visit two and comparison of the left and right sides.

To test the validity of PWV (ECG) and its correlation with PWV (carotid-femoral tonometry) a correlation coefficient was calculated between the two measures. The analysis was done using the averages of both sides and both days.

Results

The physical characteristics of all of the subjects are shown in Table 1. There were no significant group differences in age and height between the three groups. Body weight, BMI, and physical activity scores were significantly different than the yoga and the aerobic group $p<0.05$. The weights for the yoga and aerobic groups were 60±25 and 70±13 kg and for the sedentary group the weight was 87±21 kg. The physical activity scores for the yoga and aerobic groups were 8.56±1.37 and 8.04±0.82. The physical activity scores for the sedentary group were 6.29±0.94. There was also a statistical difference in the food scores between the yoga group and the sedentary group that was not seen between the yoga and the aerobic group. For the nutritional questionnaire, the higher the score the worse the nutritional status. The sedentary group had an average nutritional score of 0.83 compared with an average score of 0.40 seen with the yoga group. Blood pressure and heart rate characteristics for the three groups are presented in

Table 2. A significant difference was obtained in systolic blood pressure and pulse pressure between our yoga and our sedentary group $p<0.05$.

A one-way ANOVA was conducted to evaluate whether central stiffness measured by distensibility and pulse wave velocity was different in the three groups (aerobic, yoga, and sedentary). Mean distensibility for the aerobic, yoga, and sedentary groups are shown in Figure 2. Carotid artery stiffness measured by distensibility was not a statistically significantly different between the aerobic group and the yoga group. The p-value between the two groups was 0.26 and the effect size was 0.04. A significant difference in distensibility was seen between the yoga group and the sedentary group ($p<0.001$ with an effect size of 0.84).

Mean pulse wave velocity between the aerobic, yoga, and sedentary groups are seen in Figure 3. Central stiffness measured by pulse wave velocity showed that there was no significant difference between the aerobic group and the yoga group $p=0.21$ with an effect size of 0.08. There was a significant difference seen between the yoga group and the sedentary group $p<0.001$ with and effect size of 0.81.

Correlations between physical activity and the central stiffness measures are seen in Figure 4 and Figure 5. There was a very moderate correlation between physical activity and distensibility ($R^2=0.52$) and between physical activity and pulse wave velocity ($R^2=0.50$). Physical activity had the strongest correlation with the central stiffness measures. Age, weight, and waist-to-hip ratio all had a low correlation with our stiffness measures. All had nonsignificant correlations with both distensibility and PWV.

Comparison of measurements from visits one and two are seen in Table 3. All of the measurements taken showed good reproducibility from visit one to visit two. All of the measures had a CV<10%. The strongest reliability was seen with distensibility (Figure 6) and PWV all with coefficient of variations of less than 3%. The lowest reliability was seen with diameter change and pulse pressure both had CV of >4%.

Comparisons of measurements from the left and right carotid arteries are seen in Table 3. All measurements had a CV<10%. The lowest agreement was seen in pulse pressure and diameter change which both had a CV of >4%. The highest agreement of the left side to the right side were between with distensibility (Figure 7) and PWV, which all had CV of<3%**.**

The correlation between PWV measured by tonometry and by ECG is presented in Figure 8. There was a very strong correlation between the two measures. The correlation coefficient calculated was to be 0.93 and the prediction equation had a slope near one with an intercept of -0.59.

Discussion

This study showed that physical activity had the greatest influence on arterial stiffness. This is consistent with previous studies that have shown that physical activity has a significant influence on arterial stiffness (11, 26, 31). Tanaka et al (34) conducted a study examining the effect of regular exercise on arterial stiffness in men. The study evaluated three different physical activity categories (sedentary, recreationally active, and endurance trained) and found that the sedentary group had significantly higher arterial stiffness compared with the endurance-trained group (34). Our findings were similar to that Tanaka et al (34). Tanaka et al found that arterial compliance in his trained middle aged and older group was 20 to 35% higher than their sedentary group (34). The yoga participants in my study were moderately active and performed yoga. This study found that arterial stiffness in our aerobic and yoga group was on average 32% lower than our sedentary group. The magnitudes of the differences between our groups were similar to the magnitudes of Tanaka's study. Kupari et al (15) did a study in which he examined the association between arterial distensibility and self-reported physical activity and found a significant correlation between the two measures (R^2=0.45); people with higher self-reported physical activity had lower arterial distensibility. This study had a slightly higher correlation with arterial distensibility (R^2=0.52 distensibility and 0.50 pulse wave velocity).

As expected, the sedentary participants had significantly lower levels of physical activity than the aerobic group. However, the yoga group was more active than expected and had physical activity scores similar to those of the aerobic group. Because of this, I was unable to determine an independent affect of yoga on arterial stiffness. All of our yoga participants performed some form of inversion postures, a practice that has been shown to increase blood flow to the carotid artery during the posture (17). There are currently no studies that have looked at the effect of yoga with inversion posture on arterial stiffness, but several studies have looked at yoga and inversion postures and it's effect on the cardiovascular system and have found that people who practice yoga and inversion postures had a lower resting heart rates and systolic and diastolic blood pressures compared with people who are sedentary (1, 6, 13). Bharshankar et al (1) did a study examining the effect of yoga on the cardiovascular system. The study found that people who practiced yoga have a lower heart rate, systolic blood pressure and diastolic blood pressure; however physical activity levels of the yoga participants were not reported (1). Other studies that have examined the effect of yoga on the cardiovascular system also fail to report the physical activity level of their yoga participants (1, 13, 21). Our study suggests that physical activity levels in addition to the practice of yoga need to be measured in order to interpret the influence of yoga on cardiovascular risk factors for disease. Future studies may need to be longitudinal in order to better control for physical activity outside of yoga is controlled.

Our study also had evidence that the yoga group may have different dietary habits compared to the sedentary group suggesting that nutrition may play a role in arterial stiffness. The yoga and aerobic groups reported to eating less meat and less fatty foods than the sedentary group, and they had significantly lower BMI, waist to hip ratio, and systolic blood pressure. However, nutrition scores, BMI, and waist to hip ratio were found not to be important influences on arterial stiffness for our study (R^2=0.31, 22 and 0.05 with distensibility and 0.39, 0.15, and 0.42). All values were nonsignificant correlates with arterial stiffness. Future studies should incorporate more detailed methods of measuring nutrition and body composition.

One variable we were surprised did not influence arterial stiffness was age. Age had a correlation coefficient of 0.028 with distensibility and 0.072 with PWV. Middle aged participants (40-65 yrs) were chosen because this is the age range where stiffness starts to occur in the arteries and where different physical activity levels tend to have the greatest impact on arterial stiffness (34). Several studies have shown an age related increase in arterial stiffness and a strong correlation between age and arterial stiffness (26, 34). Tanaka et al (34) showed that across the same physical activity level (sedentary, recreationally active, and endurance trained) arterial compliance was lower in the middle aged (38-57) and older group (58-77) than in the younger group (18-37). Our age range fell within the middle to older range compared with the Tanaka study (34). Tanaka also noticed no significance difference in arterial compliance across the same physical activity level between middle aged and older group (34) so age was not the main determinant of arterial stiffness in the middle and older age range. Similar to Tanaka's study, the finding of this study was that there was no significant correlation between age and arterial stiffness in middle-aged participants.

We found that there was a very good agreement between our pulse wave velocity measures (R^2=0.91). Our study compared PWV (ECG) and PWV (carotid-femoral tonometry). Several studies have compared different ways of measuring pulse wave velocity but none have focused on ECG and carotid tonometry (18). The PWV values obtained from this study were very similar to the values obtained in other studies McEniery et al (22) study on the effects of aging on wave reflection found that in healthy middle aged adults between the age of 40-70 the average range for pulse wave velocity was 6 to 9 m/s. The age range for our study was 40-65 and our pulse wave velocity measures ranged from 6.1 to 8.0 m/s, similar to the age range of McEniery's study. Carotid tonometry is the gold standard when measuring pulse wave velocity but ECG is easier to use and less tedious. One possible limitation of ECG is that it assumes a constant isovolumetric contraction time of 0.05 seconds for everyone. For this reason, ECG may not be an accurate measure of pulse wave velocity. By using tonometry, isovolumetric contraction time does not affect the measurement of pulse wave velocity. Carotid tonometry seems to be less stable and more time consuming and a lot harder to use because of the amount of equipment needed. Our study showed that using ECG proved to be just as accurate in measuring pulse wave velocity as carotid tonometry.

We found good day-to-day reproducibility for arterial stiffness in our study. The coefficient of variation for distensibility and pulse wave velocity were 2.5 and 2.5. Liang et al (16) did a study looking at the repeatability of several different noninvasive measures of arterial stiffness including distensibility and pulse wave velocity over two visits. He found that distensibility had a CV= 10% and PWV had a CV=3.2% (16). Our study showed slightly lower CV for distensibility and pulse wave velocity than the Liang study. He reported using one value for each measurement each visit. Our lower CV may have occurred because of the repeated measures taken on visits one and two. Our study took four values for each stiffness measure each visit. We also found good reliability comparing left and right arterial stiffness (CV= 2.2 and 2.7 for distensibility and pulse wave velocity). Most research studies report measurements of carotid artery stiffness from only one (right) side (33). As people age, their arteries begin to stiffen and if they develop some type of arterial disease, arteriosclerosis, and arterial stiffness may occur at different levels on different sides of the body. It is important to know if healthy middle-aged adults experience different levels of stiffness on different sides of the body in the central arteries. Our study found that there was no difference in carotid artery stiffness between the left and right carotid arteries so there is no need to measure the left and right separately.

Limitations

One limitation of the study was that the participants were not asked directly how much if any high intensity resistance training they did (80-95% of 1RM). Subjects who perform regular resistance training may have greater central arterial stiffness (25). All that we can say for our study was that none of the participants recorded on the physical activity questionnaire that they were performing any high intensity resistance exercise. We also did not record the intensity of the aerobic exercise performed by our yoga and aerobic activity groups, we only asked how many days a week and for long they exercise. Previous studies have shown that intensity of aerobic exercise may influence arterial stiffness (11). None of the subjects reported performing strenuous aerobic exercise on their questionnaire. Another limitation is that the yoga participants were not asked how long they stayed in head down postures on a given day so the quantity and type of inversion yoga was not recorded. Future studies will be needed to tease out the potential effects of inversion yoga on arterial stiffness.

Another limitation was seen in the body composition and nutritional questionnaire. Body mass index was used to measure body composition. In the future maybe a better measure of body composition needs to be used in order to get a more valid assessment. The nutrition questionnaire used made it hard to see the true nutrition status of each participant because only four questions were asked and the amount or type of food the participants ate was not quantified. Future studies may need to include a food intake chart or a way to measure cholesterol directly.

Conclusions

Yoga participants had significantly lower arterial stiffness than sedentary participants but no difference in arterial stiffness compared to aerobic participants. Because most of the yoga participants reported aerobic physical activity levels similar to our aerobic group, we were not able to conclude that yoga produced an independent reduction in arterial stiffness. We also noticed that the yoga participants had better nutritional scores than the sedentary group and were not different from the aerobic group, so cholesterol intake or other nutritional factors may have played a role in the different stiffness levels of the participants. This study also does not show a negative influence of yoga on arterial stiffness. Future, studies that investigate the effect of yoga on arterial stiffness should try to control for the physical activity level of the yoga participants. All of our measures proved to be extremely reliable and there was good agreement between the left and right carotid arteries. Our PWV measurements using ECG and carotid tonometry showed good correlation with each other indicating that using ECG to measure PWV is valid. Using ECG seems to be an easier and less tedious way to measure PWV.

Table 1: Selected Subject Characteristics (Mean±S.D.)

	Age	Female/ Male (Total)	Height (m)	Weight (kg)	BMI (kg/m^2)	W-H ratio	Food Score	Physical Activity Score
Aerobic Group	45-59	4/6=10	1.69±0.10	70±13	24.3±1.9	0.8±0.1	0.53±0.3	8.04±0.82
Yoga Group	42-54	5/3=8	1.72±0.08	60±25	22.9±2.9	0.8±0.1	0.4±0.3	8.56±1.37
Sedentary group	44-60	3/6=9	1.77±0.13	87±21*	27.2±3.54*	0.9±0.1	0.8±0.3*	6.29±0.94*

*****$p<0.05$ significance against yoga group

Table 2: Subject Blood Pressure Characteristics

	Female/Male (Total)	SBP (mmHg)	DBP (mmHg)	PP (mmHg)	HR (beats/min)
Aerobic	4/6=10	114±11.8	71.4±6.7	43±6.9	60±11.4
Yoga	5/3=8	108±8.5	65±6.5	43±4.3	62±8.8
Sedentary	3/6=9	127±11.23*	75±10.9*	52±5.6*	68±9.6

*p<0.05 significance against yoga group

Table 3: Comparison of Measurements Day 1 and Day 2

	HR (beats/min)	SBP (mmHg)	DBP (mmHg)	PP (mmHg)	Diameter Change (m)	DC (kPa)	PWV ECG (m/s)	PWV (carotid-femoral) (m/s)
Visit 1	61±10.2	113±25.2	70±15.8	45±11.0	0.61±0.11	18.26±3.5	7.72±1.85	7.56±1.49
Visit 2	61±10.8	112±25.1	70±15.5	43±10.9	0.60±0.20	18.4±3.4	7.73±1.86	7.57±1.48
Correlation	0.98	0.96	0.92	0.84	0.82	0.98	0.99	0.98
CV	2.7%	6.2%	3.3%	6.6%	7%	2.5%	2.4%	1.8%

No significant differences between the left and right side were found for all measurements

Table 4: Comparison of Measurements Left versus Right Side

	Heart Rate (beats/min)	SBP (mmHg)	DBP (mmHg)	PP (mmHg)	Diameter Change (m)	DC (kPa)	PWV ECG (m/s)	PWV (carotid-femoral) (m/s)
Left	63±10.1	116±12	70±9.0	46±6.7	0.61±0.11	18.3±3.4	7.69±1.89	7.67±1.73
Right	64±11.1	117±14	71±8.6	46±7.5	0.60±0.11	18.4±3.5	7.76±1.82	7.72±1.64
Correlation	0.96	0.95	0.93	0.85	0.82	0.98	0.97	0.98
CV	3.4%	6.2%	4.0%	6.8%	6.9%	2.2%	1.8%	1.7%

No significant differences between the left and right side were found for all measurements

Figure 1: ECG and Carotid-Femoral Tonometry Setup and Waveforms

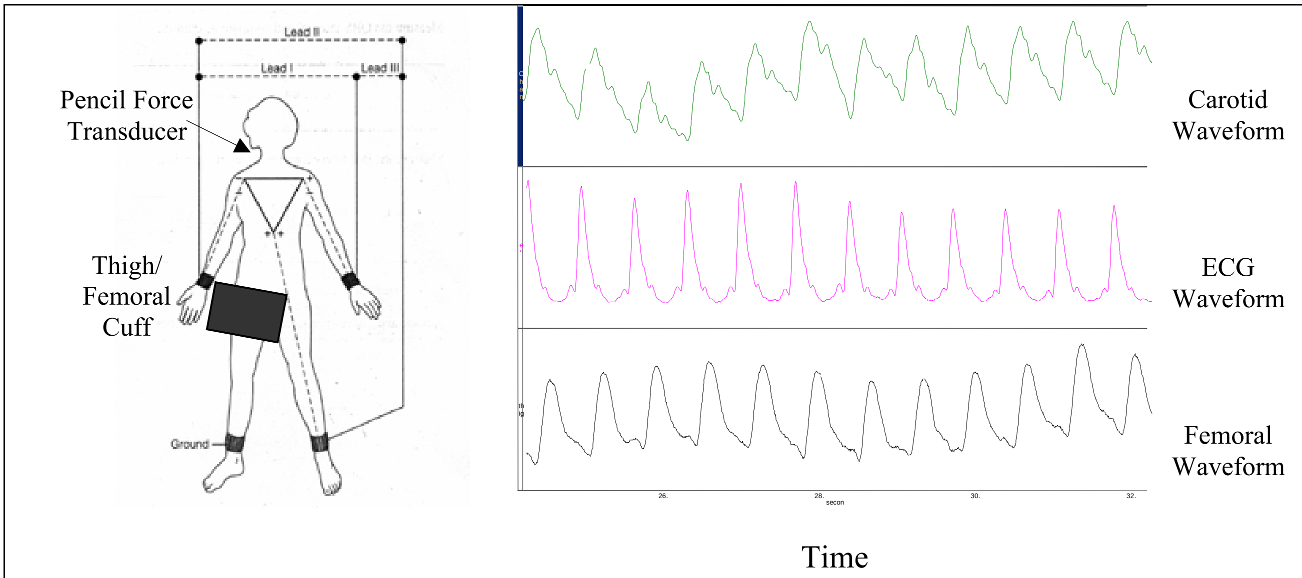
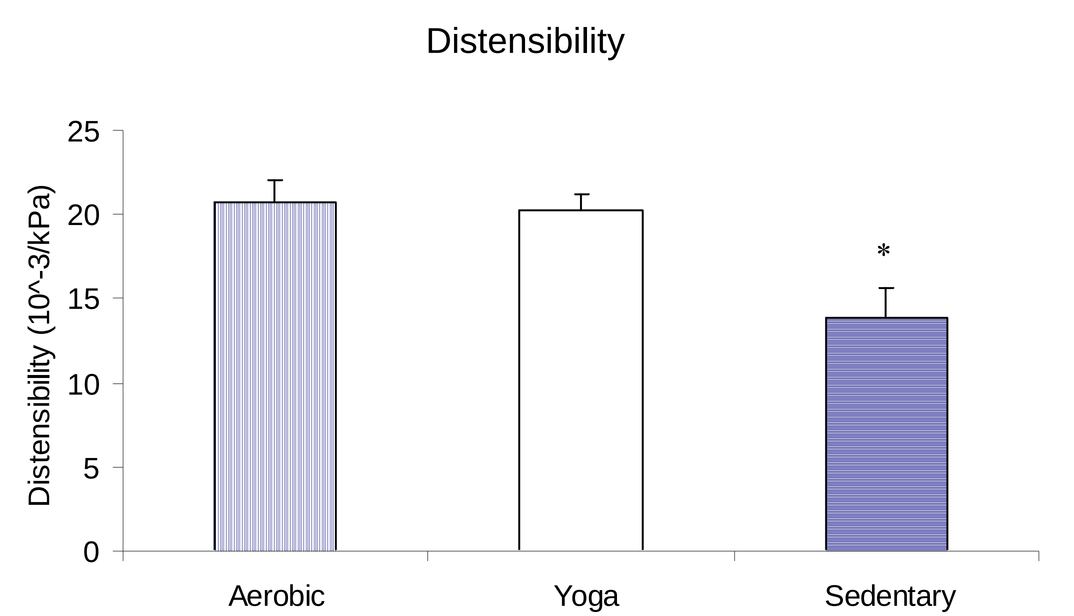


Figure 1 shows the set up of the by a force transducer, ECG, and the femoral cuff and the waveforms produced by by the force transducer, ECG, and the femoral cuff.

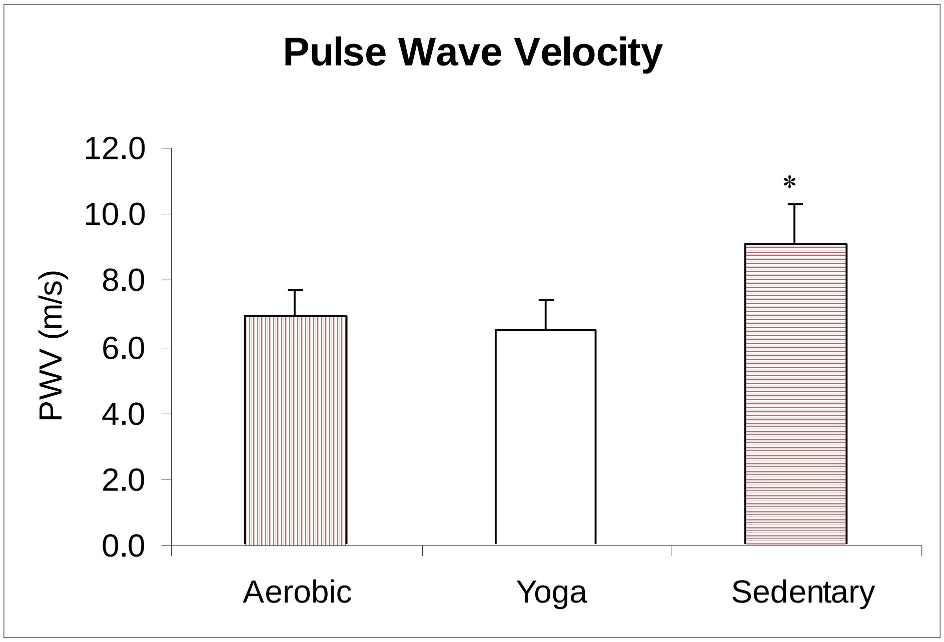
Figure 2: Distensibility of Each Group



*P<0.05 shows significance against yoga groups. Data reported as means±S.D.

Figure 2a shows the distensibility of each group. The sedentary group had significantly lower distensibility than the aerobic and the yoga groups.

Figure 3: Pulse Wave Velocity of Each Group



*P<0.05 shows significance against yoga groups. Data reported as Means±S.D.

Figure 3 shows the pulse wave velocity of each group. The sedentary group had significantly higher pulse wave velocity than the aerobic and the yoga groups.

Figures 4: Physical Activity Correlated with Distensibility

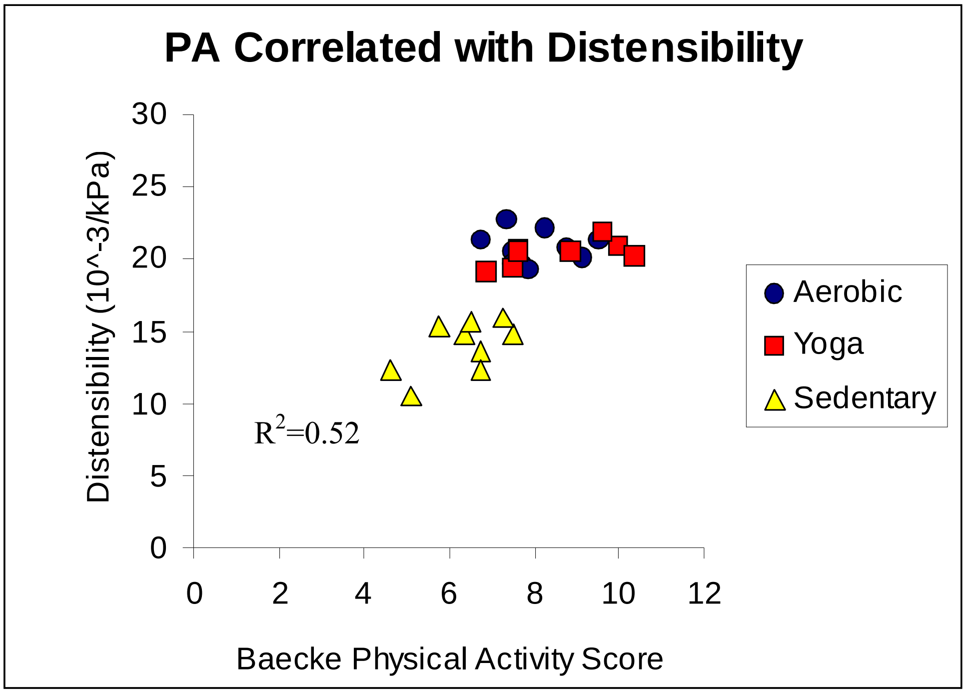


Figure 4 shows that there was a strong correlation between PA score with distensibility R^2=0.52 with p<0.01.

Figure 5: Physical Activity Correlated with PWV

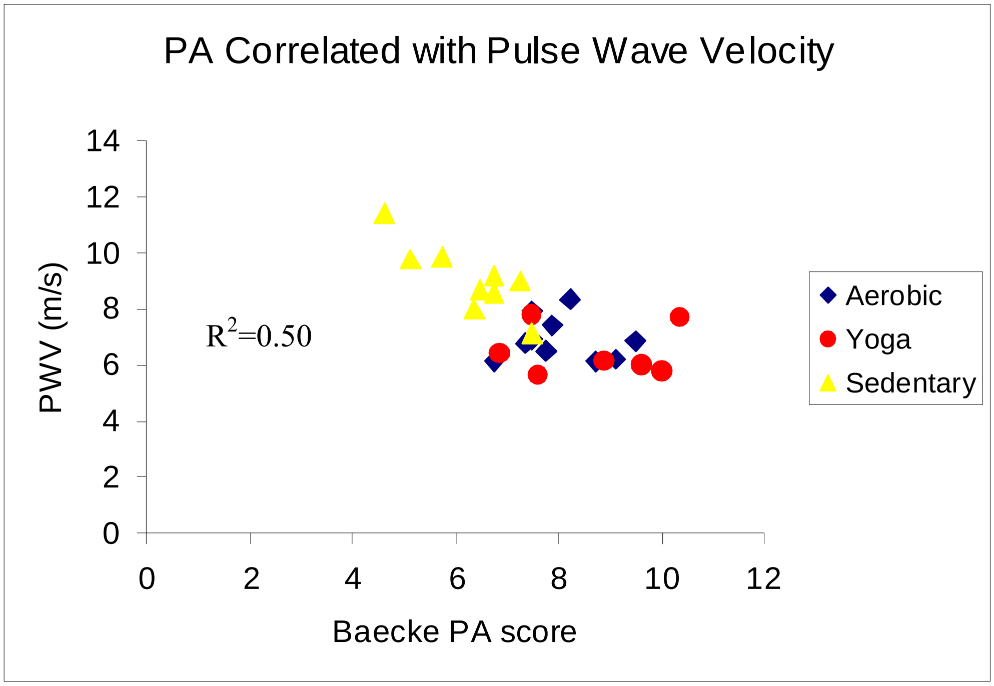
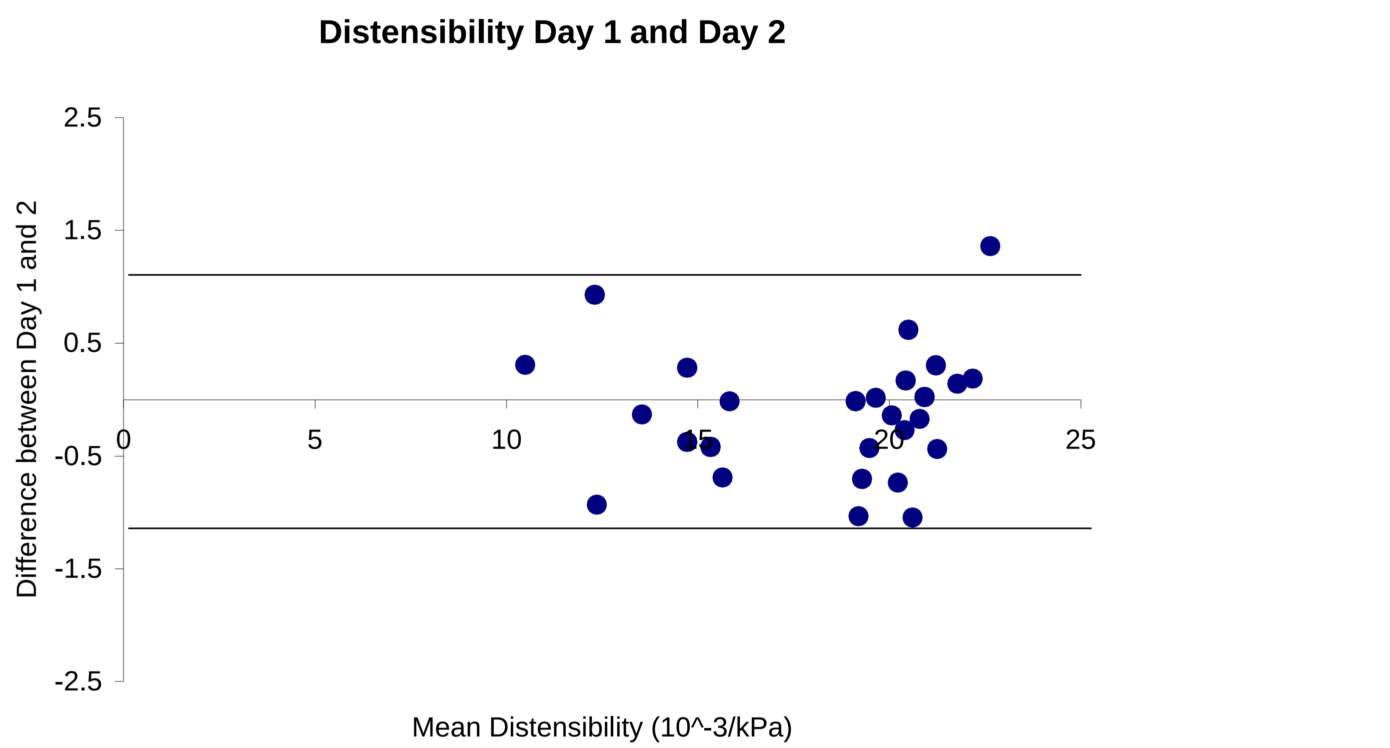


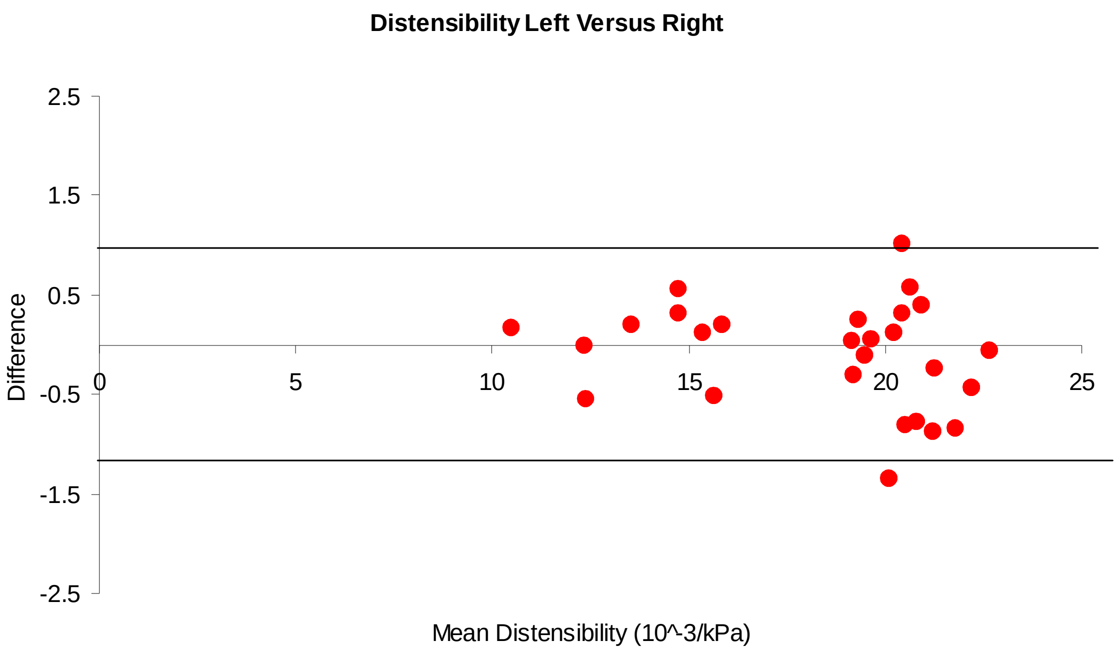
Figure 3b shows that there was a strong correlation between PA score and PWV R^2=0.50 with p<0.01

Figure 6: Bland Altman Plot Day 1 versus Day 2



The graph shows the means ±2 S.D. Figure 4 shows a plot of distensibility means of the right and left sides for day 1 and day 2 versus the difference in day 1 and day 2 measurements. CV=2.5% for distensibility

Figure 7: Bland Altman Plot Left versus Right



The graph shows the means ±2 S.D. Figure 5 uses the average of the right sides on day 1 and day 2 and the left sides for day 1 and day 2 and plots the mean of the right and left sides versus the difference between the right and left sides. The CV between the right and left side was 2.2%

Figure 8: Correlation Between Pulse Wave Velocity Measures

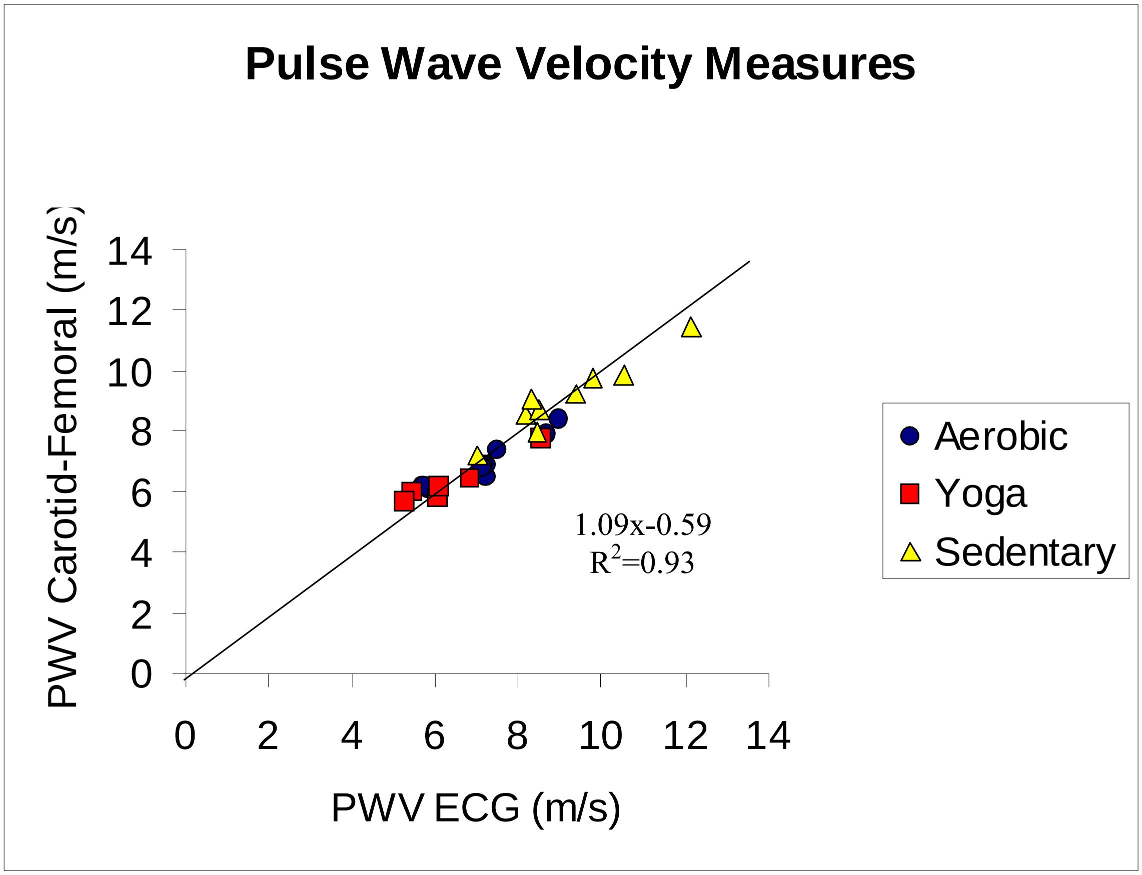


Figure 6 shows the correlation between PWV taken by ECG and PWV taken by carotid tonometry. There was a strong correlation between the 2 measures of PWV. R2=0.93 with a slope of 1.09 and an intercept of -0.59.

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CHAPTER FOUR

Summary and Conclusion

It is clears that aerobic activity plays a role in decreasing age related increases in central artery stiffness. The effect of yoga on carotid artery stiffness had not been researched until this study. Some studies have investigated the effect of yoga on the cardiovascular system and have concluded that yoga has a positive effect on heart rate, systolic blood pressure, and diastolic blood pressure (1, 6, 9). With this study, it is still unclear what effect yoga has on carotid artery stiffness. This study was a cross-sectional study comparing people who do yoga with those who were aerobically active and those who were inactive. One variable that we did control for in the yoga group was physical activity level. We found that the yoga participants were just as physically active outside of yoga as our aerobic group. The studies that have investigated the effects of yoga on the cardiovascular system (1, 6, 9) do not report the physical activity levels of their yoga participants outside of yoga and this study suggests it is a variable that should be considered Also several different forms of yoga exist and some yoga forms involve aerobic type of activities, the aerobic component of yoga may lead to the cardiovascular adaptations. A future possibility would be to do a longitudinal study in which a person is trained to do yoga and their physical activity level outside of yoga is controlled.

One variable that we were surprised that did not have more of an effect on carotid artery stiffness was age. Several studies have shown an age related increase in arterial stiffness. Our study saw no correlation between age and arterial stiffness. The age range chosen for our study was middle age (40-65 years). It could be that once people reach middle-age that the increase in arterial stiffness is not so much due to age but factors associated with getting older like decline in the amount of physical activity or fitness level. Tanaka et al (34) noticed that middle age and older men have stiffer arteries than younger men regardless of physical activity level but he did not see a difference in arterial stiffness between the middle-aged men and older men when comparing people with the same physical activity level. Tanaka et al.'s study suggests that once a person reaches middle age, it is not age but physical activity level that influenced carotid artery stiffness. Our study suggests the same results.

Another feature of our study was inversion postures in yoga. All of our yoga participants performed some form of inversion yoga. Originally we wanted to see if performing this posture had any effect on reducing carotid artery stiffness because aerospace studies have shown that head-down posture increases blood flow to the carotid arteries (17). Our study recorded the number of days a subject performed the inversion posture but the amount of time in a day the participants spends in the inversion posture was not asked or recorded. Because the amount of time spent in inversion posture was not recorded, we were unable to make any conclusions about the effect of inversion posture on carotid artery stiffness. It could be that a person needs to perform inversion posture for a certain amount of time in order to see an effect on carotid artery stiffness.

Overall the study went well. However there were a few areas that need to be addressed. Tonometry was used for the first time in our lab. Because of this some of the measurements obtained were extremely noisy and difficult to calculate. We had originally planned to calculate pulse pressure at the carotid artery using tonometry but we found it difficult to quantify the amplitude of the waveforms produced by the force transducer on the carotid artery and get accurate measures of pulse pressure. However, we were able to obtain pulse wave velocity from the wave forms produced using the force transducer, femoral blood pressure cuff, and the ECG tracing. In the future a more stable way of using tonometry with the force transducer needs to be developed in order to obtain pulse pressure readings. Considering the fact that this was the first time tonometry was used in our Vascular Lab, I was pleased that we were able to obtain such reliable pulse wave velocity measurements.

We also experienced some difficulty with the automatic blood pressure machine. With some of the smaller women with a fainter pulse, the machine had difficulty detecting a pulse and would some times have to inflate several times in order to obtain a blood pressure reading. For some of those participants we had to take their blood pressure manually. Some one who worked in the fitness center and was well qualified to obtain manual blood pressures took their blood pressure.

Recruitment of the participants was more difficult than I originally expected. I was unable to recruit the amount of subjects I had originally proposed. I originally placed flyers around UGA and sent them to yoga institutions and the flyers in the yoga institutions produced the most effective means of recruiting the yoga participants. Flyers around UGA did not prove to be a very effective means of recruitment but eventually approved flyers sent to faculty university list serves did prove to be an extremely effective way to recruit sedentary and aerobically active participants.

CHAPTER FIVE

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CHAPTER SIX
Appendix a

Baecke Physical Activity Questionnaire

Name: ____________________________ID:________________________ Date:___________

1. What is your main occupation?

2. At work I sit: never seldom sometimes often always

3. At work I stand: never seldom sometimes often always

4. At work I walk: never seldom sometimes often always

5. At work I lift heavy loads: never seldom sometimes often always

6. After work I am tired: very often often sometimes seldom never

7. At work I sweat: very often often sometimes seldom never

8. In comparison with others of my own age, I think

my work is physically: much heavier heavier as heavy lighter much lighter

9. Do you play a sport? Yes No

If yes, which sport do you play most frequently? ____________________

How many hours a week? < 1 1-2 2-3 3-4 >4

How many months per year? <1 1-3 4-6 7-9 >9

If you play a second sport, which sport is it? ____________________

How many hours a week? < 1 1-2 2-3 3-4 >4

How many months per year? <1 1-3 4-6 7-9 >9

10. In comparison with others of my own age, I think my physical

activity leisure time is: much more more as much less much less

11. During leisure time I sweat: very often often sometimes seldom never

12. During leisure time I play sport: never seldom sometimes often always

13. During leisure time I watch television: never seldom sometimes often always

14. During leisure time I walk: never seldom sometimes often always

15. During leisure time I cycle: never seldom sometimes often always

16. How many minutes do you walk and/or cycle per day to and from

17. work, school and shopping? < 5 5-15 15-30 30-45 >4

Appendix b

Yoga Questions (Asked)

1. **Do you do any yoga?**
2. **Do you do any inversion yoga?**
3. **How long have you been doing inversion yoga?**
4. **How many days a week do you do inversion yoga?**

Appendix c

The University of Georgia
Health Questionnaire

This form is designed to assess your overall health status. Please complete this form to the best of your recollection and sign in the designated place.

NAME____________________ AGE_________________ DATE________

	YES	NO
1. Have you ever had heart problems? If yes, describe: ____	_____	_____
2. Do you have diabetes?	_____	_____
3. Do you have high levels of triglycerides/cholesterol in your blood?	_____	_____
4. Do you have high blood pressure?	_____	_____
5. Do you smoke? Approximately how many packs a day?	_____	_____
6. Have you ever smoked? How many years did you smoke? If no longer smoke, how many years were you a smoker? If no longer smoke, how many years since you last smoked?	______	______
7. Family history of coronary heart disease (CHD) Mother, Father, Brother-Sister with CHD prior to 50 years of age.	_____	_____

8. Are you currently taking any medication? Please name:______________________
   What is the medication for?____

9. Do you have any physical conditions, impairment, recent injury or disability (including muscle or joint problems)? If so please name: ____________________
   ____

Signature:______________________________ Date:____________