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Vascular health and mental health in collegiate female varsity athletes, club sport athletes and recreationally active women

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Abstract

The number of women participating in collegiate athletics has increased since Title IX was passed, which supports equal access to men and women in government-funded programs. Female student athletes are under increased pressure to maintain fitness while meeting academic standards, thus resulting in mental health concerns (i.e., depression and anxiety) and related poor lifestyle habits (i.e. problematic alcohol drinking and disturbed sleep quality). While high fitness imparts cardiovascular health benefits, such mental health concerns and poor lifestyle habits negatively impact cardiovascular health. Cardiovascular health is particularly concerning for women, as cardiovascular disease is a leading cause of death in this group and recent data suggest increased rates of cardiovascular health-related hospitalizations in young women. **PURPOSE:** To compare vascular health, fitness, mental health and lifestyle habits of collegiate varsity athletes, club sport athletes and recreationally active (RA) women. **METHODS:** Eight Division 1 varsity athletes (age 20±1 yrs, BMI 24.1±1.6 kg/m^2) and 12 club sport athletes (age 20±2 yrs, BMI 24.5±3.2 kg/m^2), were matched to 20 RA women (age 20±2 yrs, BMI 24.3±3.0 kg/m^2) based on age and height. Cardiovascular health assessment included measures of pulse pressure (PP) and carotid-femoral pulse wave velocity (PWV). Fitness was broadly defined as cardiorespiratory fitness, strength, flexibility and balance assessed using a YMCA Step Test and estimated VO_2max, hand grip strength, sit-and-reach and balancing on a firm and foam surface over a force platform, respectively. Generally accepted and validated questionnaires were used to subjectively assess depression, anxiety, alcohol consumption behaviors, sleep quality and physical activity. Physical activity and sleep were further objectively assessed using accelerometry. **RESULTS:** Varsity athletes had higher PP ($p<0.05$) but similar aortic stiffness ($p>0.05$) compared to club and RA. Varsity athletes had greater estimated VO_2max and average strength compared to RA ($p<0.05$). Varsity athletes spent less time in sedentary and greater time in vigorous activity assessed through the analysis of accelerometer data compared to both the club and RA women ($p<0.05$). There were no differences in anxiety or depression scores or lifestyle habits between the varsity athletes and RA. **CONCLUSION:** Despite having greater levels of fitness, more optimal physical activity habits and comparable mental health as female club sport athletes or non-athletes, female collegiate varsity athletes had higher pulse pressure. Given that the higher PP occurred concomitant with similar aortic stiffness and mean arterial pressure, we suggest that increased PP in this setting is a reflection of an exercise adaption related to cardiac structure and function.

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By

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Thesis

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Key Concepts – Lay Definitions

Athlete – For the present study, an athlete was defined as someone participating in either varsity (Division 1) or club sport athletics at Syracuse University. These women likely have sport-specific training for over 10 years.

Recreationally Active (RA) – A woman who is not participating in either varsity or club sport athletics at Syracuse University but engages in habitual exercise and/or physical activity.

Fitness – The combination of cardiorespiratory fitness, muscular strength, flexibility and balance. High fitness levels are associated with decreased risk for a number of diseases, including cardiovascular disease.

American College of Sports Medicine Physical Activity Guidelines – Adults should engage in moderate intensity cardiorespiratory exercises for over 30 minutes on at least five days per week, strength based exercises and agility/balance/coordination exercises should be completed at least twice a week, as well as stretching each major muscle group for at least 60 seconds per stretch.

> "The ACSM recommends that most adults engage in moderate-intensity cardiorespiratory exercise training for ≥30 min/d on ≥ 5d/wk for a total of ≥ 150 min/wk, vigorous-intensity cardiorespiratory exercise training for ≥ 20 min/d on ≥ d/wk (≥ 75 min/wk), or a combination of moderate- and vigorous-intensity exercise to achieve a total energy expenditure of ≥ 500–1000 MET/min/wk. On 2–3 d/wk, adults should also perform resistance exercises for each of the major muscle groups, and neuromotor exercise involving balance, agility, and coordination. Crucial to maintaining joint range of movement, completing a series of flexibility exercises for each the major muscle–tendon groups (a total of 60 s per exercise) on ≥ 2 d/wk is recommended."

Physical Activity Guidelines For Americans

> "Adults should do at least 150 minutes (2 hours and 30 minutes) to 300 minutes (5 hours) a week of moderate-intensity, or 75 minutes (1 hour and 15 minutes) to 150 minutes (2 hours and 30 minutes) a week of vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Preferably, aerobic activity should be spread throughout the week….Adults should also

do muscle-strengthening activities of moderate or greater intensity and that involve all major muscle groups on 2 or more days a week, as these activities provide additional health benefits."

Pulse Pressure – A measure of the pressure the heart generates with each contraction. This is calculated by subtracting the pressure during heart contractions (systolic blood pressure) and the pressure during heart relaxation (diastolic blood pressure). Higher pulse pressure is due to altered cardio-vascular function and may be a reflection of reduced vascular health.

Arterial Stiffness – A term referring to the properties of the blood vessels that carry blood away from the heart (i.e. arteries). Arteries are naturally elastic and stretch when the heart ejects blood into the vessel. With aging and disease, the arteries lose elasticity (i.e. increase in stiffness) and this effects how blood flow and is delivered to tissues and organs transmitted throughout the body. A stiffer artery increases risk for cardiovascular disease.

Mental health and lifestyle habits – A non-physiological factor operationally defined as depression, anxiety, alcohol consumption, sleep quality and sedentary behaviors, which are known to increase risk for cardiovascular disease.

Non-Technical Summary

What is known?

Female athletes make up nearly half of the collegiate athlete population in the United States (86). Athletes are widely considered the epitome of health because of their high fitness levels, leading to a decreased cardiovascular disease (CVD) risk. However, student athletes may be at increased risk for mental health concerns and subsequently engage in poor lifestyle habits as a means of coping with the demands of balancing athletic and academic demands. Increased anxiety, depression, and alcohol consumption may increase their CVD risk. CVD is the number one killer among women in the United States (1), and 64% of women who die suddenly from CVD have no prior symptoms (100). CVD risk, as assessed by traditional CVD risk factors such as blood pressure, cholesterol levels, family history of CVD and chronological age, may not fully explain an individual's CVD risk (33). Non-traditional measures of vascular health such as pulse pressure (the difference between systolic and diastolic blood pressure) and arterial stiffness (a reflection of the elasticity of the largest artery in the body) may offer novel insight into underlying CVD risk in young women. Increases in pulse pressure and aortic stiffness increase risk for future CVD. This study sought to examine vascular health, mental health and lifestyle habits among athletes and recreationally active (RA) young women with the overarching goal of understanding risk for CVD in young women of varying physical activity and fitness levels.

What is new and noteworthy from our results?

Finding 1: There were no differences in arterial stiffness between the athlete group and RA group, even after separating the groups based on athletic participation (varsity vs. club). However, there were differences between the varsity athletes, club athletes and RA in pulse pressure, with the varsity athletes having the highest pulse pressure.

Finding 2: There were no differences in depression/anxiety, sleep quality or alcohol consumption between the varsity athletes, club athletes and RA women. Varsity athletes spent less time in sedentary activities and more time in vigorous activities compared to the RA.

Conclusions and Implications

Collegiate varsity athletes do not appear to be at risk for mental health concerns, did not engage in risk alcohol consumption and reported similar sleep quality as other active (club sport) and less active (RA) women. Despite more optimal fitness and similar mental health compared to college-age club sport and recreationally active women, the varsity athletes had higher pulse pressure suggesting altered cardiovascular function. We suggest that the increased pulse pressure was a reflection of cardiovascular adaptations to training and not an indication of poor cardiovascular health (discussed below).

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Glossary of Terms and Abbreviations

Abbreviation	Term
CVD	Cardiovascular disease
PWV	Pulse wave velocity
PP	Pulse pressure
HR	Heart rate
RA	Recreationally active
CRF	Cardiorespiratory fitness
HRpeak	Peak heart rate during exercise
HRpost	Heart rate after one minute recovery from exercise

Introduction

Investigating cardiovascular disease (CVD) risk in females has become increasingly importantly. Frequency of hospitalizations due to heart attacks in young women (ages 35-54 years) has steadily increased over the past 20 years, while the hospitalizations for men of similar age has decreased (5). Additionally, 64% of women who die suddenly due to CVD have no prior symptoms (100).

Athletes are often considered the epitome of health because they engage in high a volume of sport-related training, including cardiorespiratory, strength, flexibility and balance training, and thereby tend to have higher general fitness levels. Accordingly, athletes tend to have lower cardiovascular disease (CVD) risk than non-athletes and tend to live longer due to the health benefits associated with exercise (43). However at the collegiate level, many stressors surface while balancing academic and athletic commitments, leading to mental health concerns and negative lifestyle habits. Presence of mental health symptoms, such as increased anxiety and depression, are associated with increased risk for CVD (64), specifically hypertension and myocardial infarction (101).

The majority of research investigating the intersection between mental health and physical health has been done in men however; initiatives such as Title IX have substantially increased female athlete participation (126). Female athletes now comprise approximately 44% of the National Collegiate Athletic Association (NCAA) student-athletes overall and 47% at the Division 1 level (86). Despite this, female athletes are twice as likely to develop depression as male athletes (137). Although fitness is known to decrease the risk of developing CVD, mental health concerns and related poor lifestyle habits increase the risk of CVD. Assessing and managing CVD risk is particularly important in women because CVD is among the top causes of death among women in the United States and recent data suggest increased rates of cardiovascular health-related hospitalizations in young women (1, 5). As such, primordial prevention is of paramount importance.

CVD risk is conventionally assessed using traditional risk factors, such as blood pressure, cholesterol, family history of CVD and chronological age (33). These traditional risk factors do not always fully explain the differences in female-specific CVD risk, and residual cardiovascular risk remains even after management of modifiable traditional risk factors (106). That is, even if one were to control traditional CVD risk factors using medication, the individual may still be at risk for CVD. Clinicians and researchers have consequently looked to non-traditional CVD risk factors to improve prediction and detection of CVD risk. Two emerging non-traditional measures of CVD risk are pulse pressure (PP) and arterial stiffness. PP is calculated as the difference in systolic and diastolic blood pressures, and has been shown to be an independent risk factor for cardiac events (104). As arterial walls stiffen, there is an increase in systolic pressure with a maintenance or decrease in diastolic pressure, leading to increasing PP. Increased PP is associated with increased CVD risk and offers insight into CVD morbidity and mortality beyond insight provided by systolic or diastolic blood pressure alone (105). Arterial stiffness, or reduced artery elasticity, has also been shown to predict CVD (131) and incidence of coronary artery disease and stroke (73). Additionally, arterial stiffness is an independent predictor of CVD mortality (76). In women, both PP and arterial stiffness have been clinically useful in the diagnosis of heart failure, hypertension and aortic valve disease (29), and may provide further insight into sex differences in these conditions above traditional CVD risk factors.

Athletes have been shown to have more elastic arteries than non-athletes (42) and this may contribute to lower CVD mortality compared to non-athletes (43). Exercise with subsequent increases in fitness from sport-related training is known to have numerous benefits for the cardiovascular system (94). Fitness is defined by the American College of Sports Medicine (ACSM) as comprising of four domains: cardiorespiratory fitness (CRF), strength, flexibility and balance (44). As part of their training, athletes tend to develop higher levels of CRF, strength, flexibility and balance in order to compete in their sport at a high level. Interestingly, high CRF (42), high muscular strength (38, 39) and increased flexibility (139) have each been shown to be associated with lower arterial stiffness. Due to these high fitness levels and improved cardiovascular health, athletes tend to live longer than non-athletes (43).

Although fitness is known to decrease the risk of developing CVD, poor mental health and related lifestyle habits may increase the risk of CVD. Collegiate athletes are under pressure to balance being successful in both the classroom and on the playing field with commitments to scheduled practices and additional training sessions. Athletes now live in highly charged, intense and publically exposed environment, termed the “fish bowl effect” (124). As a result of these unique stressors, athletes may be highly susceptible to mental health concerns and symptoms. College-aged adults in general are more likely to be affected by mental health symptoms, such as depression and anxiety, compared to other adults. In both the general population (84, 85) and in athletics (108, 137), females are more commonly affected by these mental health concerns than male athletes. While facing these public stressors, athletes may attempt to manage symptoms by engaging in risky and unhealthy lifestyle habits. Alcohol consumption may be particularly high among student athletes, with one study stating 35% of athletes report binge drinking, defined as four or more drinks per drinking session, during the season and 60% of athletes report binge drinking out of season (75). Social commitments, as well as other athletic or academic responsibilities may lead athletes to de-emphasize a good night sleep, as defined by getting at least seven hours of sleep per night (63, 135). Heavy alcohol consumption is also associated with sedentary behaviors, or activities that require little to no movement (44) in women, but not men (4). Studies have shown anxiety, depression and alcohol consumption may lead to poor sleep quality (63, 140), and sedentary behavior outside of athletic commitments (114, 136). Depression and anxiety (110, 141), poor sleep quality (26), binge drinking (133) and sedentary behavior (52) are all known to increase arterial stiffness, thereby increasing CVD risk. Since women are more prone to develop and die from CVD then men, and female athletes are experiencing greater prevalence of mental health symptoms, it is important to investigate how lifestyle habits related to the stressors associated with athletics influences female CVD risk.

With more female athletes now than ever, is it important to investigate the overall health of these athletes. Defining the relationship between fitness and vascular health, as well as mental health and related lifestyle habits and vascular health will provide insight into CVD risk. The purpose of this study was to determine if athletes truly are healthier than non-athletes, by investigating vascular health, fitness, mental health and lifestyle habits in three groups of women varying in their athletic and exercise/activity experiences: varsity Division 1 athletes, club sport athletes and recreationally active non-athletes (RA). Club sport athletes and

RA women will serve as two control groups to compare the varsity athletes to, thereby determining if level of athletic participation influences vascular health.

Specific Aims

Aim 1: To compare vascular health among female varsity athletes, club sport athletes and recreationally active non-athletes (RA). Vascular health was assessed using arterial stiffness (measured by pulse wave velocity [PWV]) and pulse pressure (PP).

Hypothesis 1: It was hypothesized that the varsity athletes would have lower PWV and PP, indicative of healthier vasculature.

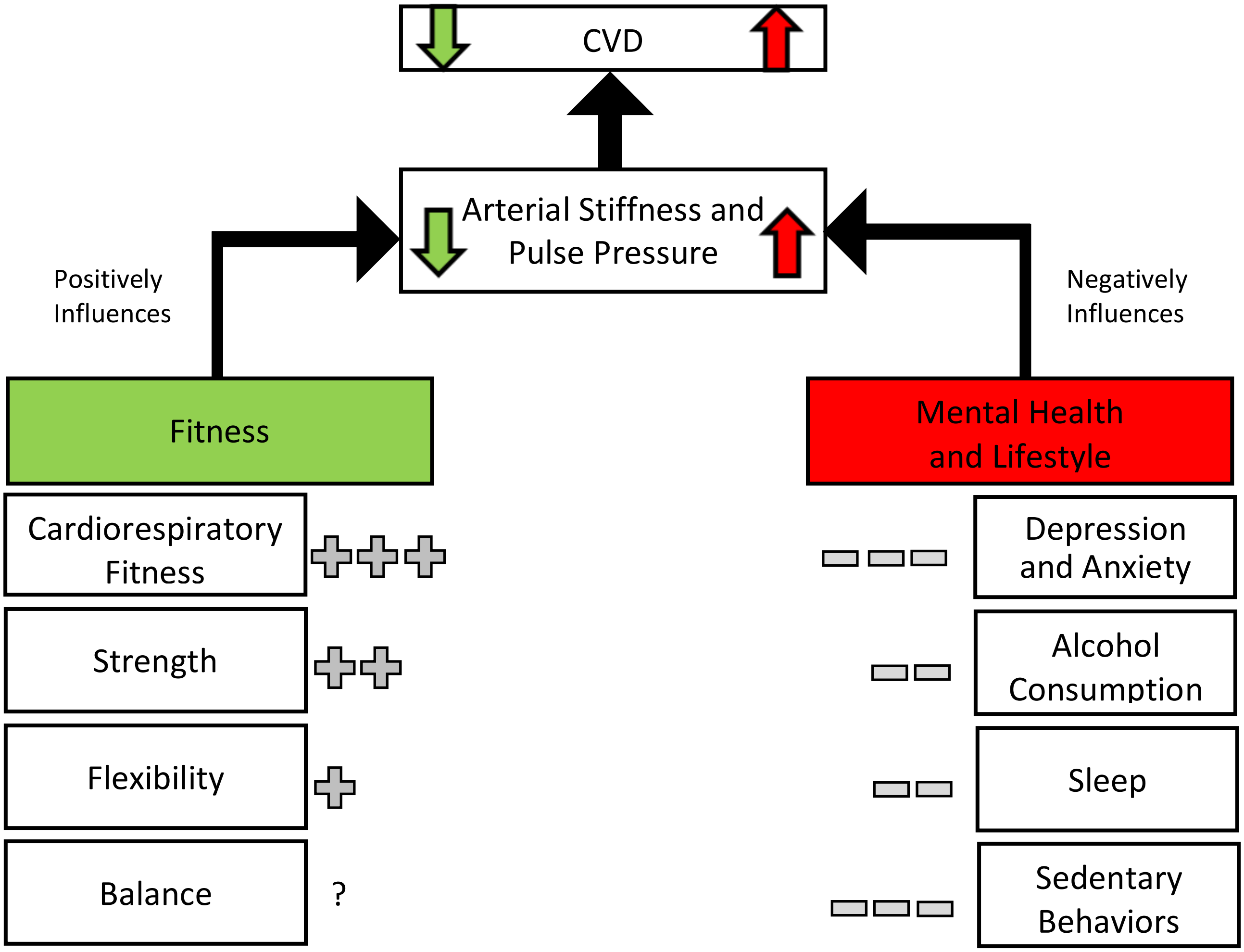
Aim 2: To compare mental health and related lifestyle habits among female varsity athletes, club sport athletes and RA. Mental health and lifestyle habits were assessed through accepted and validated questionnaires to assess depression (Center for Epidemiological Studies Depression Scale [CES-D]), anxiety (Generalized Anxiety Disorder [GAD-7]), alcohol consumption behaviors (Alcohol Use Disorders Identification Test [AUDIT]), sleep quality (Pittsburg Sleep Quality Index [PSQI]) and physical activity (International Physical Activity Questionnaire [IPAQ]). Accelerometers were used to qualitatively assess physical activity.

Hypothesis 2: It was hypothesized that varsity athletes would have greater reported depression and anxiety, greater risky drinking behavior, worse sleep quality and more time spent in sedentary behavior than the RA, indicating poor mental health and negative lifestyle behaviors.

Theoretical Model

A theoretical model was created to provide a visual representation of the relationship between vascular health, fitness, mental health and lifestyle factors, see figure below.

Cardiovascular disease (CVD) is an important public health problem among women in the United States, and can be assessed using non-traditional measurements such as arterial stiffness and pulse pressure. These vascular measures are positively influenced (indicated by green) by high fitness levels, with strong evidence to support a positive (+++) relationship to cardiorespiratory fitness, moderate (++) relationship with strength, emerging (+) information about flexibility and little (?) information about balance. Collegiate athletes may also experience concerning mental health symptoms or engage in unhealthy lifestyle habits which have known negative effects (indicated by red) on vascular health. Depression and anxiety, moderate to severe alcohol consumption, poor sleep quality and sedentary behaviors are all moderately (--) or strongly (---) negatively associated with vascular health.



CVD
Arterial Stiffness and Pulse Pressure
Positively Influences
Negatively Influences
Fitness
Mental Health and Lifestyle
Cardiorespiratory Fitness
Strength
Flexibility
Balance
?
Depression and Anxiety
Alcohol Consumption
Sleep
Sedentary Behaviors

Review of Literature

Background

Cardiovascular disease remains the most prominent cause of death in the US with men and women having fairly similar incidence of CVD (100). However the frequency of hospitalizations due to heart attacks in young women (ages 35-54 years) has steadily increased over the past 20 years, while the hospitalizations for men of this age range decreased (5), underscoring a need for more research on CVD in women. CVD is among the leading causes of death in women (1), yet 64% of women who die suddenly due to cardiovascular issues have no prior symptoms (100). The risk of CVD is typically assessed by investigating traditional risk factors, which are strongly related to the likelihood a person currently has or will develop CVD. These include hypertension, hyperlipidemia, metabolic conditions such as diabetes or renal diseases, as well as age, smoking and obesity and other CVDs, such as peripheral artery and cerebrovascular dysfunction (60, 99). These traditional risk factors may not fully explain a person's risk for developing CVD; therefore clinicians and researchers have looked to non-traditional risk factors to aid in risk prediction for CVD.

Non-Traditional CVD Risk Factors – Pulse Pressure and Arterial Stiffness

Cardiovascular burden may be investigated through pulse pressure (PP), which is an indirect estimation of arterial compliance, or the capacity of the artery to respond to changes in volume (32, 105). PP is the calculated through the difference between systolic blood pressure (SBP) and diastolic blood pressure (DBP), see Figure 2.1. As arterial walls stiffen, there is an increase in systolic pressure with a maintenance or decrease in diastolic pressure, leading to increasing PP and thereby CVD risk (22, 105). PP can be assessed either peripherally at the brachial artery (bPP) by using brachial SBP and DBP (listed in the figure below as pSBP, pDBP and pPP), or centrally at the aorta (cPP) using central SBP (cSBP) and central DBP (cDBP). Investigating PP peripherally and centrally indicates pressure amplification, or the change in pressure waveform throughout the arterial system (7, 96). In general, pressure is higher in the periphery (i.e. brachial) compared to centrally (i.e. carotid) owing to narrowing and stiffening of the vessels. This amplification helps blood flow perfusion to distal target organs while also minimizing cardiac work. Thus, assessing cPP may provide better insight about CVD risk due to proximity to the heart (7). PP increases with age and has been recorded as greater in women than men (113). PP is also an independent risk factor for CVD, such as myocardial infarction (104). Although PP is indicative of vascular health as a proxy of arterial stiffness, this may be measured directly through measuring pulse wave velocity.

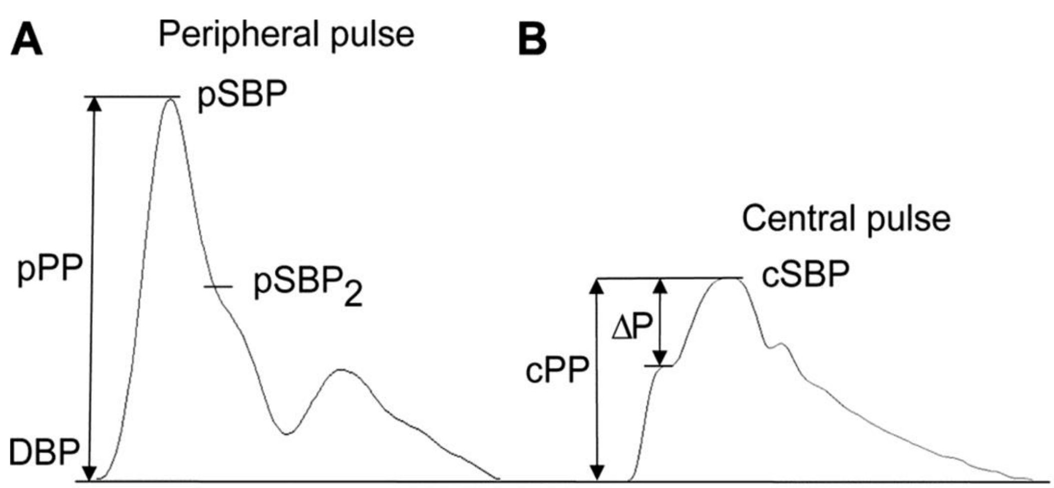


Figure 2.1. Calculation of peripheral (A) and central (B) pulse pressure. Peripheral pulse pressure (pPP) (or brachial as used above), in panel A is calculated by the difference in systolic blood pressure (pSBP) and diastolic blood pressure (DBP). Central pulse pressure (cPP) in panel B is calculated by the difference in central systolic blood pressure (cSBP) and diastolic blood pressure (DBP). Adapted from Munir (78).

Arterial stiffness is a measure of artery's ability to stretch and recoil to effectively deliver blood to muscles and target end organs such as the brain and kidneys (87, 122). Healthy arteries are elastic and deliver blood to the periphery at a low pressure, while unhealthy arteries are stiff and deliver blood to the periphery at a high pressure, see Figure 2.2 (18, 87). This has been shown to provide more clinically relevant information related to CVD risk than standard risk factors (122). Additionally, arterial stiffness has been shown to predict CVD (131), incidence of coronary artery disease and stroke (73), as well as an independent predictor of CVD mortality (76).

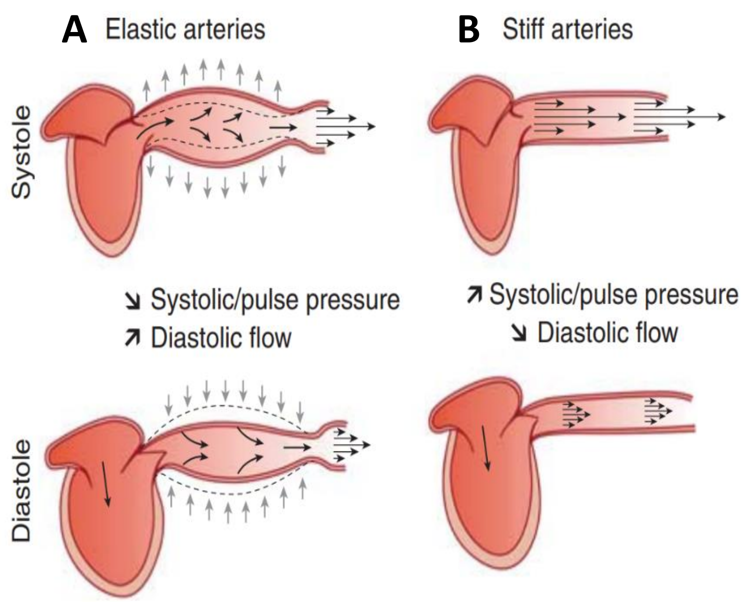


Figure 2.2. The difference in elastic (A) and stiff arteries (B) and the relationship to pulse pressure. (A) The elastic arteries expand and recoil to deliver smooth and slow blood flow to the periphery. This allows systolic blood pressure to decrease and increases to diastolic flow, corresponding to lower pulse pressure. (B) The stiff arteries delivery blood more quickly to the periphery, corresponding to a higher systolic pressure, decreased diastolic flow and a higher pulse pressure. Adapted from Briet (22).

The gold standard method to measuring arterial stiffness is through pulse wave velocity (PWV). PWV calculates the transmission of energy within the arterial wall, whereas blood velocity represents the movement of mass (blood) through the blood column (22), see Figure 2.2. The velocity of the blood pressure wave moving through the artery indicates the stiffness of the vessel. A stiffer artery produces a faster pulse wave traveling away from the heart (carotid artery) and toward the leg (femoral artery).

Although arterial pressure (measured during blood pressure) and blood flow (measured as PWV) is different, these concepts are related. Arterial stiffness clinically corresponds to an increased systolic blood pressure and a decrease in diastolic pressure, resulting in increases to PP (91). Conversely, healthy elastic arteries correspond to decreases in systolic pressure (or SBP) and increases to diastolic flow (or DBP), resulting in lower PP (79). Both PP and arterial stiffness have been clinically useful in the diagnosis of heart failure, hypertension and aortic valve disease in women (29), and may provide further insight into sex differences in these conditions.

While indicators of vascular health such as PP and PWV increase with normal aging, age related changes may be attenuated by lifestyle and maintaining a high level of cardiorespiratory fitness (128). Adults who are not meeting physical activity guidelines are seen to have an increase for the development of CVD 2.4 years sooner than adults meeting physical activity guidelines (19). Sedentary behavior increases arterial stiffness and thereby CVD risk (16, 122). Conversely, arterial stiffness may be improved by improvements to lifestyle habits, such as increasing physical activity (52). Literature suggests athletes have less arterial stiffness than non-athletes, indicative of healthier vasculature (67, 116). However, in as little as two years after retirement from elite competition, arterial stiffness in female athletes has been shown to increase (62). This striking finding is likely due to the decrease in cardiorespiratory fitness and muscular strength, emphasizing the importance of fitness and physical activity to mitigating age-associated vascular dysfunction. Each construct of fitness and its' relationship to vascular health in athletes is discussed in the following section.

The National Collegiate Athletic Association (NCAA) lists that over 460,000 student athletes participate in 24 sports every year across three skill levels, with Division I being the highest level of competition. Initiatives such as Title IX promote equal participation in athletics among women (126). Accordingly, female athletes comprise approximately 44% of the NCAA student-athletes overall and 47% at the Division 1 level (86). Syracuse University is a Division I school with 18 varsity sports. Many athletes who leave high school and do not want to compete at the NCAA level choose to participate in club sports. Syracuse University has over 40 different club sports teams for a student to choose from to continue his/her involvement with a sport. The varsity sport time commitment typically includes practices for more than two hours a day, six days a week during the season in addition to competitions, with the out of season time commitment being slightly less and no competitions, per mandates by the NCAA (2). Unfortunately, there are no available national statistics on participation of club sports or regulations on time commitment or competition schedules. Syracuse University's Recreation Services states there are nearly 1,500 students on a club sports team, with practice commitments ranging from one to five times per week, with competition against other institutions' club sport teams ranging from seasonal double-headers to approximately once a month throughout the academic year. Part of the training at the collegiate varsity or club sport level includes various strengthening, endurance, balance and stretching exercises to optimize performance. By the time an athlete is participating in collegiate sports, s/he has likely been completing this type of fitness training for at least 10 years.

As alluded to previously, owing to their higher general fitness levels, athletes are often considered to be the epitome of health. Indeed, fitness does confer cardio-protection, or a lower risk of CVD. Athletes tend to have lower CVD risk than controls and tend to live longer due to the health benefits associated with physical activity and exercise (43). The most recent guidelines for prescribing exercise for adults were released in 2011, which explain the daily exercise recommendations for healthy living (44). These guidelines recommend all adults include cardiorespiratory and resistance exercises, combined with flexibility and neuromotor exercises to improve and maintain fitness and health across multiple physical domains (cardiorespiratory endurance, muscular strength, flexibility/mobility and balance) (44). A collegiate athlete typically meets and exceeds these exercise recommendations through his/her competition and practice schedules, based on the 20 hours per week of countable athletic hours determined by the NCAA (2). Elite athletes have been shown to live longer (43, 65), likely due to athletes having greater cardiorespiratory fitness (CRF) (119) and muscular strength (116). It is assumed that athletes also tend to have higher flexibility and better balance compared to non-athletes because athletes tend to stretch more and engage in activities or movements that require more postural control. Each domain of fitness may have a separate but important effect on improving overall cardiovascular health.

Fitness

Cardiorespiratory Fitness

All of the varsity sports at Syracuse University require athletes to have high levels of cardiorespiratory fitness (CRF). CRF reflects the body's ability to supply oxygen and nutrients through the circulatory system during exercise, which allows the muscles to continue exercising. Some sports require greater CRF than others due to the greater running or aerobic demands in those sports, such as soccer compared to volleyball. Higher levels of physical activity are associated with higher CRF levels, and thereby lower CVD risk (36).

CRF has been a marker of health in the ACSM guidelines since its inception. The current ACSM guidelines suggest adults engage in moderate-intensity cardiovascular exercise training for greater than 30 minutes per day on more than five days per week (44). Vigorous-intensity cardiovascular exercise may be completed instead, for greater than 20 minutes per day on three or more days per week (44). Higher levels of CRF, corresponding to greater activity levels, are associated with decreased CVD risk (120). The degree of arterial stiffness is less in aging individuals who engage in regular cardiorespiratory exercise (42). Similarly, in a young population, high levels of CRF may also be protective from developing CVD and deter age-related changes to arterial stiffness (42, 121, 122). Although routine exercise may decrease blood pressure, contributing to a lower PP in the general population, high training volumes over many years may alter the "typical" blood pressure response seen with moderate physical activity (12).

Muscular Strength

Athletes routinely engage in strength-based exercises to be successful in athletic competitions. Elite athletes have greater strength than non-elite competitive athletes (31, 45). This is also evident between collegiate athletes, with Division 1 athletes tend to be stronger than lower level collegiate athletes (95). Greater hand grip strength is seen in athletes who compete in sports with greater arm torque, such as overhand throwing or serving in tennis or volleyball (31, 132). Muscular strength assesses the maximum amount of force a muscle can exert at one time. This component of the ACSM fitness guidelines suggests adults perform resistance exercises for the major muscle groups two or three days per week (44). Higher muscular strength has been demonstrated to be beneficial for decreasing CVD risk (6, 112, 118). Specifically in women, there is also a decrease in CVD risk factors such as type-two diabetes with higher strength (112). Part of this is related to the assumption that higher muscular strength is associated with more optimal body composition and lower risk of obesity. Additionally, individuals with higher muscular strength have been shown to have a reduced risk of hypertension and metabolic syndrome (6) as well as lower arterial stiffness (39). Data collected recently in the Human Performance Laboratory supports the favorable vascular effects of muscular strength, noting an inverse relationship between relative upper body strength and arterial stiffness specifically in women (59).

Flexibility

The third component of the ACSM fitness guidelines is flexibility. Muscular flexibility is the lengthening of muscles resulting in increased range of motion. The ACSM guidelines suggest stretching exercises be completed in major muscle-tendon groups on greater than two days per week to ensure the full range of motion is achieved in the muscles (44).

The specific relationship between flexibility and CVD is not well established, nor is the relationship between flexibility and non-traditional CVD risk factors. Emerging literature has identified a relationship between flexibility and arterial stiffness suggesting middle age and older adults with greater flexibility have healthier arteries, indicated by a lower PWV (139). Poor flexibility has been associated with greater cardio-ankle vascular index (an index of arterial stiffness) in men of all age groups and older women, but not in younger women (88). However, the fitness level of these younger women (average age 24) was not clearly indicated, and overall fitness may influence flexibility (88). This emerging finding may be related to estrogen's effect on flexibility, similar to the known influences of estrogen on the cardiovascular system (88). Estrogen offers considerable cardio-protection in pre-menopausal women, as demonstrated with higher cardiovascular indicators during the early follicular phase of the menstrual cycle (3).

Balance

The fourth ACSM guideline includes incorporating neuromotor exercises, such as balance exercises two or three days per week, which may be incorporated into the resistance exercises (44). Balance is ability to maintain an upright and stable position, through an integration of the vestibular, visual and muscular system through proprioception. Balance can be improved during strength training by completing unilateral exercises (15), or during flexibility-inducing exercises such as yoga poses.

While the impact of strength on the cardiovascular system is established and some literature suggests a relationship between flexibility and the cardiovascular system, the relationship exclusively between balance and the cardiovascular system is less clear. Emerging evidence supports a cardiopostural system, linking balance and the cardiovascular system (138). The skeletal muscle, which is a major component of postural control, influences systolic blood pressure through the skeletal muscle pump (129). While standing, the muscles of the lower leg assist with the return of blood to the heart through venous return. Xu proposes a muscle-pump baroreflex, which prompts venous return due to body positional changes, similarly to the cardiac baroreflex response (138). The influence of the proposed cardiopostural system and CVD risk is unclear, as well as the relationship between postural control and arterial stiffness has yet to be investigated.

Although implications of balance and CVD remain to be seen, balance remains important to ensure proper form and safety during athletic activities. During activities such as running, weight is shifted from one foot to the other, while activities such as a squat rely on balance to correctly perform the movement. Balance training has been shown to improve some sport performance and reduce the likelihood of (21) or be predictive of (35) sports-related injuries. Additionally, female athletes have demonstrated significantly better postural stability compared to male athletes (55).

Mental Health and Lifestyle Habits

Collegiate athletes may not always be the epitome of health that is publically assumed (80). Extending beyond physical health, mental health may have a profound impact on the cardiovascular system and overall CVD risk. Collegiate athletes are not immune from the pressures that non-athletes also face. Like non-athlete peers, collegiate athletes are susceptible to mental health concerns (such as anxiety and depression), poor sleep quality and may engage in risky behaviors that compromise health (such as alcohol consumption and sedentary behaviors). Additionally, collegiate athletes are under increased pressure to balance being successful in both the classroom and on the playing field with commitments to training sessions in addition to scheduled practices. Athletes live in highly charged, intense, emotional and publically exposed environments termed the "fish bowl effect" by Tricker in 1990 (124). As a result of these unique stressors, athletes may be highly susceptible to mental health symptoms and engage in negative behaviors to cope with this environment (124). Nearly 30 years after the "fish bowl" theory was proposed, the "fish bowl" has only amplified with the increase in media outlets, particularly social media, putting athletes into even more publically exposed environments. This allows new opportunities for the athletes to be scrutinized and criticized, further increasing the likelihood of mental health problems and development of negative lifestyle behaviors.

Depression and Anxiety

Depression is a common mood disorder among adults in the United States which affects how a person feels, thinks and handles everyday activities (84). As of 2017, depression affected 7.1% of United States adults, including 8.7% of females and most commonly affected adults between the ages of 18-25 (84). Sub-syndromal depression is characterized by clinical symptoms of depression that do not meet the clinical diagnostic criteria for depression (40), but remain associated with the development of other mental health conditions such as anxiety (97). Depression is typically grouped with anxiety disorders as both are mental health conditions and associated symptoms are thought of as psychosocial stressors. Anxiety disorders are characterized by excessive anxiety and related behavioral disturbances that interfere with daily life (85). Anxiety disorders affect 19.1% of United States adults, 23.4% of females (compared to 14.3% of males) and 22.3% of adults 18-29 (85).

Depression and anxiety are considered psychosocial stressors, which are associated with risk for CVD (64), specifically hypertension and myocardial infarction (101). A recent meta-analysis found an increased risk of CVD deaths with psychological stressors, even at subclinical levels (102). The increased development of CVD with depression and anxiety remains even after adjustment for known traditional CVD risk factors (64). Non-traditional CVD risk factors such as arterial stiffness have been assessed in adults with depression and anxiety disorders (110). Current depressive and/or anxiety disorders have been associated with a positive dose-response effect to changes in arterial stiffness (110). This dose-response effect means participants with longer exposure to depression symptoms had increased stiffness, and thereby increased CVD risk (110). A population that is often exposed to increases in depression and anxiety are young adults transitioning from home life to college.

College life brings in new stressors for young adults, in addition the stressors of competing on an athletic team, leading to increased likelihood to develop depression or anxiety symptoms (140). Approximately 24% of athletes reported clinically relevant depressive symptoms, as defined by a score greater than 16 out of 60 on the Center for Epidemiological Studies Depression Scale (CES-D) (109, 137). Similar to the national statistics of depression, female athletes reported significantly higher for depressive symptoms overall (137, 140), as well as a greater percentage of female athletes reported clinically relevant depressive symptomology compared to male athletes (137). Anxiety is also more prevalent in female athletes compared to male athletes (137), and seen more frequently in aesthetic sports such as gymnastics, swimming and figure skating (108).

Alcohol Consumption

Adults suffering from mental health concerns such as depression and anxiety may use substances such as alcohol to manage these symptoms (11). Unhealthy alcohol consumption has a cooperative relationship with depression and anxiety, meaning alcohol use may lead to symptoms of depression and anxiety or depression and anxiety may lead to self-medication remedies such as alcohol abuse (50). Binge drinking is defined by The National Institute on Alcohol Abuse and Alcoholism as a pattern of drinking that brings a person's blood alcohol concentration to 0.08 grams or greater (127). For a typical female adult, this is four or more drinks in about two hours (127). Risky drinking behaviors are defined as drinking behavior that elevates blood alcohol concentration to 0.05 grams (127). These excessive drinking behaviors are most common among 18-24 year olds and more commonly male (37); however women have shown the greatest increase in risky drinking between 2001-2001 and 2012-2013 (49).

Alcohol consumption has a U or J-shaped relationship with CVD, with light to moderate consumption reported to lower CVD and high alcohol intake associated with increased CVD and mortality (48). Emerging literature has suggested ingesting a small amount (<1 standard drink) acutely decreases pulse wave velocity (88). Conversely, greater PP is reported with increasing drinks per day and age (133) and long-term heavy alcohol consumption is associated with accelerated arterial aging in men (90). This study also included women, however was not statistically powered to capture the consistent heavy alcohol consumption, which would correspond to increases in arterial stiffness (90) and thus, further research in women is necessary. It is important to note that heavy/binge drinking is also associated with cigarette smoking, less exercise and poor diets, which are known CVD risk factors and may further contribute to increased CVD mortality (48).

When looking specifically at female athletes, 60% of athletes reported engaging in binge drinking out of season, with 35% of athletes reporting binge drinking during the season (72). Qualitative research has shown Division 1 athletes may have team rules against alcohol use or their athletic schedules provide less opportunity to drink than their peers (72). Upon retirement, former athletes tend to consume more alcohol than non-athletes, particularly if they compete in team sports (61), highlighting the importance of investigating alcohol consumption in a collegiate athletic population.

Sleep

As mentioned previously, adults suffering from mental health concerns such as depression and anxiety may use substances such as alcohol to manage these symptoms (11). However, the use of alcohol may decrease sleep quality, potentially leading to greater anxiety about sleep habits (27). The American Academy of Sleep Medicine and the Sleep Research Society recommends adults sleep seven or more hours per night on a regular basis (135). Adults who sleep less than seven hours per night are at an increased risk for weight gain and obesity, diabetes, hypertension, heart disease/stroke and depression (25, 135). Additionally, adults who regularly sleep greater than nine hours per night are also at an increased risk for adverse CVD outcomes, demonstrating a U-shaped association between sleep and CVD risk (25). Poor sleep quality due to frequent disturbances may also negatively influence arterial stiffness (26), though other studies suggest no relationship between sleep and arterial stiffness (26, 62).

As mentioned in the earlier section, young adults are introduced to new stressors upon entering college, particularly college athletes who balance these stressors in addition to the athletics obligation (140). Collegiate athletes tend to sacrifice sleep due to academic, athletic and social demands (63). Accordingly, over 42% of athletes in one study were classified as poor sleepers by the Pittsburg Sleep Quality Index (PSQI) and nearly 40% of athletes in this study reported less than 7 hours of sleep per week day (70). This lead to 51% of athletes reporting daytime sleepiness and 0% of athletes reporting they are "never" tired (70). Due to this information, the NCAA recently released a position paper on the importance of sleep and good sleep quality for collegiate athletes (63). This highlights the relationship between sleep and athletic performance, likelihood of injury/illness, mental health and academic performance (63). This paper also suggests educating athletes on the importance of sleep, including sleep screening into pre-participation exams and provides coaches with evidence-based sleep education (63).

Sedentary Behaviors

Sedentary behavior also has a cooperative relationship between depression and anxiety, as adults who are more sedentary tend to report higher depression and anxiety symptoms and adults who are experiencing depression or anxiety symptoms tend to spend more time sedentary (53). These sedentary behaviors are also seen more commonly in women, but not men, who report heavy alcohol consumption (4).

Sedentary behavior is characterized by activities that involve little to no movement, such as sitting, and exert between 1-1.5 metabolic equivalents (METs) (92), whereas physical inactivity means a person does not meet the recommended physical activity guidelines. Physical activity guidelines have been created to encourage less sedentary time due to the known adverse effects of sedentary behavior (44). The United States Physical Activity Recommendations was most recently updated in 2018 to include recommendations about both physical activity and the dangers of sedentary behaviors (34). An adult who spends a great amount of time engaging in moderate to vigorous physical activity may counter-act the harmful effects of high volume of sitting (34). Coronary heart disease (134) and body size (51), metabolic syndrome, diabetes and CVD (78) are all positively associated with time spent in sedentary activity, and remain independent of time spent in moderate-vigorous activity, contrary to the suggested evidence above (51). Additionally, there is an inverse relationship between total sitting time, or sedentary behaviors, and CRF (36, 52) independent of physical activity (52). High amount of time spent sitting is associated with higher PP and arterial stiffness (52).

Although athletes are considered the epitome of health, an athlete may spend a substantial amount of time in sedentary activities. Athletes can be both incredibly active during training session and spend large amounts of time being sedentary during non-training hours. This is evident in elite soccer players that have been recorded spending 79%, or over eight hours, of their non-training time in sedentary activities (136), while elite rowers have been recorded spending over 11.5 hours per day sedentary (114). Sedentary behavior may also predict body fatness in elite athletes (56). When changing from a highly active state, to a sedentary state, there is a reduction of muscle and insulin sensitivity which may lead to increase adipose tissue storage and subsequent weight gain (17). People who routinely exercise are more likely to control their weight than people who do not routinely exercise, which contributes to a healthy body composition and decreased likelihood of obesity (122). When an athlete is no longer in competition season or retires completely, s/he changes from a highly active state to a sedentary state, thereby increasing the likelihood of weight gain and the likelihood of developing CVD.

Implications of Vascular Health and Mental Health After College

Collegiate athletes must adjust to a new lifestyle upon graduation. These athletes no longer have rigorous practice schedules and may not be involved in organized sports for the first time in their life. People who routinely exercise are more likely to control their weight than people who do not routinely exercise, which contributes to a healthy body composition and decreased likelihood of obesity (122). When an athlete retires, s/he may change from a highly active state to a sedentary state, thereby increasing the likelihood of weight gain and the likelihood of developing CVD. Additionally, former athletes tend to consume more alcohol than non-athletes, particularly if they compete in team sports (61). The CVD impact of these risky behaviors during college-competition years may be concealed by high fitness levels and the development of CVD may not be immediately seen. However, with normal aging, a decrease fitness, and an increase in poor lifestyle habits, these former athletes may be at a high CVD risk. Managing CVD symptoms and maintaining a low CVD profile in youth reduces likelihood of developing CVD later in life (68, 111); therefore athletes should be encouraged to engage in healthy behaviors in all aspects. In as little as two years after retirement, female athletes may demonstrate increases in arterial stiffness, further validating the CVD implications of retirement from college athletics (62). Previous research suggests retirement should be addressed with athletes to manage this identity change to ensure a smooth transition into a new life phase (75). Because of this growing trend of unhealthy behaviors during athletic competition years with negative implications and potential consequences later in life, programs such as *Moving On!* have been established (98). This NCAA funded program was designed to teach college athletes about healthier lifestyle habits and discourage sedentary behaviors due to the known negative impact sedentary lifestyle has on the cardiovascular system (98). However, these programs and resources are not prevalent enough and athletes still have high rates of mental health symptoms and unhealthy lifestyle habits.

Importance of Potential Findings

Female athletes make up nearly half of the collegiate athlete population (86). With heart disease as the leading cause of death among women in the United States followed closely by stroke (1), and the frequency of hospitalizations due to heart attacks in young women steadily increasing (5), it is important to investigate the CVD risk of female collegiate athletes. Non-traditional indicators of CVD health, such as arterial stiffness and pulse pressure (PP), are used to further evaluate CVD risk. Arterial stiffness has been shown to predict CVD (131) and incidence of coronary artery disease and stroke (73) as well as be an independent predictor of CVD mortality (76). Athletes are typically viewed the “epitome of health” due to high fitness such as CRF, strength, flexibility and balance measures levels associated with training schedules. However fitness is not the only indicator of health, and collegiate athletes may also have concerning mental health symptoms or lifestyle habits which are negatively associated with CVD health. Defining the relationship between fitness and vascular health, as well as mental health and lifestyle habits and vascular health will provide insight into CVD risk in this growing population. The purpose of the present study was to provide insight into the overall health status of female athletes and non-athletes by investigating vascular health, fitness, mental health and lifestyle habits to determine CVD risk.

Methodology

Participant Characteristics

This study enrolled a total of 40 female participants, eight varsity athletes, 12 club sport athletes and 20 recreationally active (RA) non-athletes, between the ages of 18-25. A varsity athlete was defined as a woman who participated in Division 1 athletics at Syracuse University, club sport athlete was defined as a woman who participated on a club sport team at Syracuse University, while RA was defined as a woman who does not participate in Division 1 or club sport athletics. The 20 woman RA group was selected from a larger sample of participants based and matched to the entire athlete group (n=20) on the following factors: age, height and race. Participants were non-obese (body mass index [BMI] <30 kg/m^2), had no known cardiovascular, metabolic, or pulmonary diseases and were non-cigarette smokers.

All participants signed an informed consent that was approved by the Institutional Review Board at Syracuse University prior to data collection. Participants were instructed to come to the Human Performance Laboratory at Syracuse University for two visits. For the first visit, participants were requested to abstain from caffeine, alcohol or any dietary supplements before testing, to refrain from strenuous exercise for 12 hours, and to arrive at the laboratory after a 3 hour fast. The first visit included assessments of body composition and fitness. Upon completion of the first visit, participants were fitted with an accelerometer to wear for the subsequent nine days. For the second visit, which included vascular assessment and blood draw, participants were requested not to consume caffeine, alcohol or any dietary supplements for 12 hours, to refrain from strenuous exercise for 24 hours, and to arrive at the laboratory after a 12 hour fast. The second visit was completed during the early follicular phase of the menstrual cycle (days 1-7) to avoid influence of menstrual hormones on the vasculature. Additionally, questionnaires such as health history, mental health symptoms and lifestyle habits were completed online via a REDCap link. See Figure 3.1 for study design and updated theoretical model with methodology on page 36.

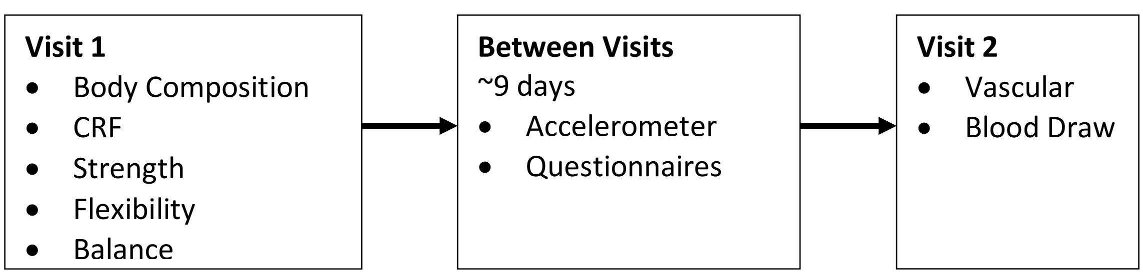


Figure 3.1. Overall study design

Vascular Assessment

Arterial function was measured in the supine position after at least seven minutes of rest. A blood pressure cuff (Omron; Kyoto, Japan) was placed on the participant's left upper arm. The blood pressure cuff measured the systolic (SBP) and diastolic (DBP) blood pressures. From these values, pulse pressure (PP) was calculated (SBP-DBP). PP was calculated for both peripheral blood pressure at the brachial artery (bPP) and centrally at the aorta (cPP) using the method described below.

Applanation tonometry (SphygmoCor; AtCor Medical, Sydney, Australia) technique was used to assess PWV, see Figure 3.2. The distance from the suprasternal notch and carotid pulse, and the distance between the suprasternal notch and the femoral pulse were measured with a tape measure to determine the aortic path length to the nearest millimeter. Blood pressure waveforms from the carotid and the femoral artery were captured over a 10 second period along with electrocardiogram tracings for simultaneous R-wave gating. PWV was calculated using the time delay between the carotid/femoral waveforms and the transit distance between the carotid and femoral arteries. This time delay was assessed as the time from peak R-wave from simultaneous ECG gating to the foot of the corresponding pressure waveform.

Figure 3.2. The applanation tonometer measuring the carotid pulse. The tonometer was also placed on the femoral pulse. Images obtained from the Human Performance Lab.

Stroke volume was calculated by an oscillometric digital BP monitor (DynaPulse; Vista, CA). This derives brachial artery distensibility from arterial pressure signals obtained from a standard cuff sphygmomanometer. The pressure waveform was calibrated and incorporated into a physical model of the cardiovascular system, assuming a straight tube brachial artery and T-tube aortic system (123).

A finger stick blood draw was completed during the second visit, while the participant was 12 hours fasted. A single-use lancet was used to obtain a droplet of blood and analyzed by a point-of-care device (Cholestech; Hayward, CA) to determine lipid profile and blood glucose.

Fitness

Body Composition

Standing height and weight was measured using a stadiometer and electronic scale respectively, with the participants wearing no shoes and light clothing. Height was measured to the nearest 0.5 centimeter (cm) and weight was measured to the nearest 0.05 kilogram (kg).

BMI was calculated as weight (kg)/height (measured in meters [m])^2. Body composition was assessed via air displacement plethysmography (BodPod; COSMED, Concord, CA) to determine body fat according to manufacturer's specifications (41).

Cardiorespiratory Fitness

Cardiorespiratory fitness was assessed through a submaximal step test. The Young Men's Christian Association (YMCA) Step Test was developed as a low cost and minimal equipment alternative to a maximal exercise test, which includes expensive equipment, a long protocol and may not be appropriate for all participants (57). Participants were asked to wear a HR monitor (Polar; Bethpage, NY) and step onto a 12-inch bench height at a set metronome frequency for three minutes (14). Supine baseline heart rate (HR) was obtained during a 5 minute collection period. Then the metronome was set to a 24 step cycles per minute (96 beats per minute on the metronome), and participants were asked to step on the box 72 times (step up-up-down-down). HR was monitored continuously during the step test to determine a peak heart rate (HRpeak). At the conclusion of the test, participants were escorted to a chair for three minutes of recovery. Heart rate recovery (HRpost) was recorded one minute after the step test and has been shown to be a strong indicator of cardiovascular fitness (117). Estimated VO_2max was calculated using the McArdle estimated VO_2 equation (74)

$$= 65.81 - (0.1847 * \text{recovery heart rate in bpm})$$

Strength

Strength was assessed using a hand dynamometer (Jarma; Lafayette, IN). In the seated position, participants were asked to squeeze the dynamometer with their dominant hand as hard as possible for three seconds. This was repeated for a total of three trials, with one minute of recovery between trials. Average strength was assessed by taking an average of the three trials, while maximum strength was the greatest value. Hand grip strength has previously been validated as an accurate indication of overall strength (16).

Flexibility

Flexibility was assessed using the Canadian Trunk Forward Flexion (sit-and-reach) protocol. Participants were instructed to sit on the floor with their feet against the sit-and-reach box (Baseline Evaluation Instruments; White Plains, NY). Participants were instructed to contract their hip flexors and abdominal muscles and reach their arms out as far as they can along the box. The furthest distance reached was recorded, and then repeated for a total of three trials. The average of the three trials, as well as the furthest distance achieved was recorded. This protocol is widely accepted to assess flexibility (54).

Balance

Standing balance was measured using a balance tracking platform (Balance Tracking System; San Diego, CA), see Figure 3.3. Balance is achieved through integration of proprioception, vestibular and visual systems. The protocol described below seeks to eliminate or reduce the feedback for one or more of these systems to determine balance.

Briefly, the force platform has four strain gauge sensors located on each corner of the rectangular plate which can detect changes to force (89). Participants stood on the board without shoes and hands on their hips and feet shoulder width apart for four trials, under four conditions, with each trial lasting 20 seconds. The protocol for each condition was exactly the same. Participants were asked to maintain their posture position while moving as little as possible for 20 seconds. The first trial of each condition is a familiarization trial. The subsequent three trials were exactly like the familiarization trial, and averaged to provide results for that condition. This protocol was completed under four conditions: eyes open standing on the balance board (EOB), eyes closed standing on the balance board (ECB), eyes open standing on a foam pad (EOF) and eyes closed standing on a foam pad (ECF). A member of the research team stood close to the participant to ensure she did not lose her balance and fall off the board. The balance tracking platform has been previously validated to detect changes in center of pressure (COP) (89). Variables collected during this assessment include path length and distance, see Figure 3.3.

While the participant was on the balance board, a tracing of her movements were recorded, see Figure 3.3 Panel A Trial 1. The path length (highlighted in the red circle below), was used as a proxy for postural sway magnitude, and assessed the average COP length in centimeters (47). Larger path lengths indicated greater postural sway (47). The distance (highlighted in the red box below), is a measure of the average distance from the center of pressure point. This was calculated using the following formula: distance = $([COP_{x2} - COP_{x1}]^2 + [COP_{y2} – COP_{y1}]^2)^{0.5}$, where COP_{x1} and COP_{x2} correspond to the medial and lateral distances from COP and COP_{y1} and COP_{y2} correspond to the anterior and posterior distances from COP (47).

Data was sampled at 25 Hz for a total of 500 data points during each 20 second trial (47). Both path length and distance are indicators of postural control and standing balance.

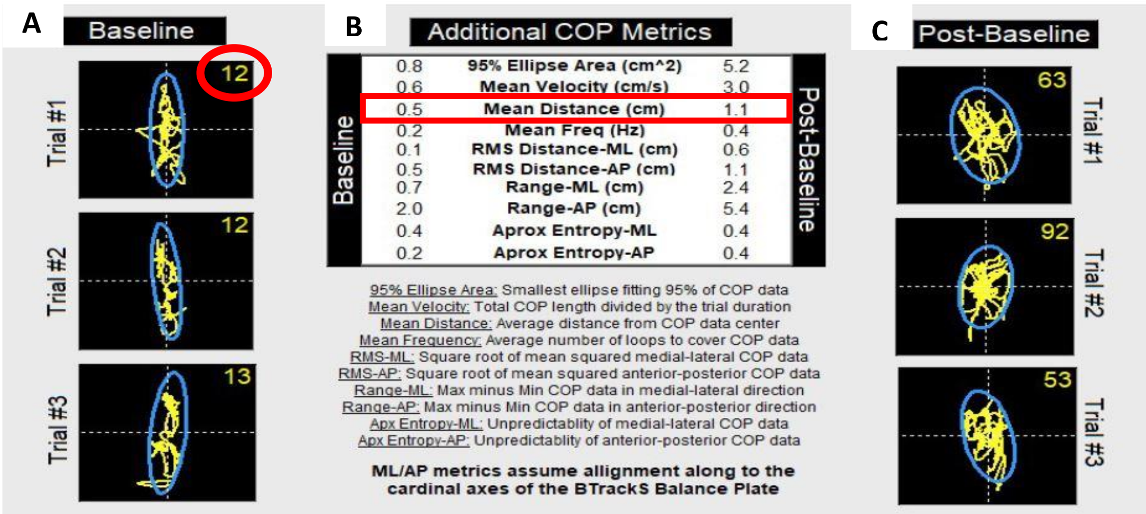


Figure 3.3. Sample output from the force plate from Baseline (eyes open on the board (EOB) shown in panel A), tracings from the most recent post-baseline (eyes closed on the foam pad (ECF) shown in panel C) and a comparison of the different center of pressure metrics collected (panel B). This output demonstrates the most dramatic changes seen to the balance variables by comparing the easiest condition (EOB) to the most challenging (ECF), however all of these variables are collected during the other conditions as well (eyes closed on the board or eyes open on the foam pad). The red circle highlights the path length for each trial during that condition, which clearly show the most recent post-baseline (C) is associated with more movement than the most recent baseline (A). Panel B represents the additional center of pressure (COP) metrics assessed, including the mean distance highlighted in the red box. Image obtained from the Human Performance Lab.

Mental Health and Lifestyle Assessment

Mental health symptoms and lifestyle habits were assessed through survey questionnaires sent out via REDCap links. Participants were emailed a link to the REDCap questionnaires after completing Visit 1 and requested to complete these prior to Visit 2. The questionnaires included a Health History Questionnaire, Center for Epidemiological Studies Depression Scale (CES-D), Generalized Anxiety Disorder (GAD-7), Alcohol Use Disorders

Identification Test (AUDIT), Pittsburg Sleep Quality Index (PSQI), and the International Physical Activity Questionnaire (IPAQ), see Appendix 3-7. Accelerometers were given to the participant to quantitatively assess physical activity over a 10 day period.

The CES-D was used to assess depression scale using 20 questions (109). The survey was scored from 0-60 which reflects the number of reported symptoms and their duration, with higher scores indicating more depression symptoms (109). A score greater than 20 is considered clinically relevant symptoms of depression (130).

The GAD-7 was used to assess anxiety using 13 questions (115). Each question was scored from 0-3, with total scores ranging from 0-39 (115). A score of five represents mild anxiety, a score of 10 represents moderate levels of anxiety and possible diagnosis of generalized anxiety disorder (to be confirmed by further evaluation) and a score of 15 represents severe anxiety (115).

The AUDIT was used to assess alcohol consumption (107). This 10 question survey was scored between 0-4, with scores ranging from 0-40 (107). Scores greater than eight indicate harmful drinking behaviors, and greater than 15 indicate hazardous drinking behaviors (107).

The PSQI was used to assess sleep quality (23). This survey comprised of 19 self-rated questions and five questions rated by a bed partner or roommate if applicable (23). The initial 19 items were rated 0-3 and used to create seven components of sleep: duration of sleep, sleep disturbance, sleep latency, day dysfunction due to sleepiness, sleep efficiency, overall sleep quality and need medications to sleep. The seven sleep components were each given a score based on the participant’s answers and then added up to give a Global PSQI score, between 0-

21 (23). Scores greater than five indicate poor sleep quality. This questionnaire has been previously used in a college athlete population (70).

Physical Activity/Sedentary Time

Physical activity was assessed via accelerometers (wGT3X-BT, ActiGraph; Pensacola, FL) and the IPAQ. Participants were instructed to wear the accelerometer on the right mid-axillary line for nine full days and requested to remove the monitor only for water based activities (bathing or swimming). A complete dataset included seven days of data collection, each with 10 or more hours of wear time per day. The accelerometer is a triaxial monitor, which records a count for every movement measured in each direction. Non-wear time was defined as a period with ≥60 minutes with consecutive zeros, allowing up to two minutes with 1-100 counts per minute (cpm). Sleep period time (SPT) was calculated as the elapsed between bedtime and wake time. Wear time was considered if three minutes with 1-100 cpm or any minute with >100 cpm. Once each minute was classified, a set of rules were applied to identify bedtime and wake time (103). Although multiple SPTs were possible, no instance of multiples was included in the final analysis. Finally, the SPT was examined for non-wear and if more than 90% of the minutes included in the SPT were classified as non-wear, the whole SPT was considered invalid and reclassified as non-wear. Cut-points were used to identify the amount of time spent in moderate intensity (2020 cpm) or vigorous intensity (5999 cpm) (125). Accelerometers have been previously validated to accurately represent activity levels and sleep (9, 10, 125), and this methodology has been used previously in our study group (9, 10).

The IPAQ was used to determine physical activity from the preceding seven days (30). The IPAQ is a 7 question survey asking about the amount of time spent in moderate activity, vigorous activity and sedentary activities, and then converted into metabolic equivalents (METS) (30). The MET per week for each level of activity were calculated by duration x frequency per week x MET intensity (30).

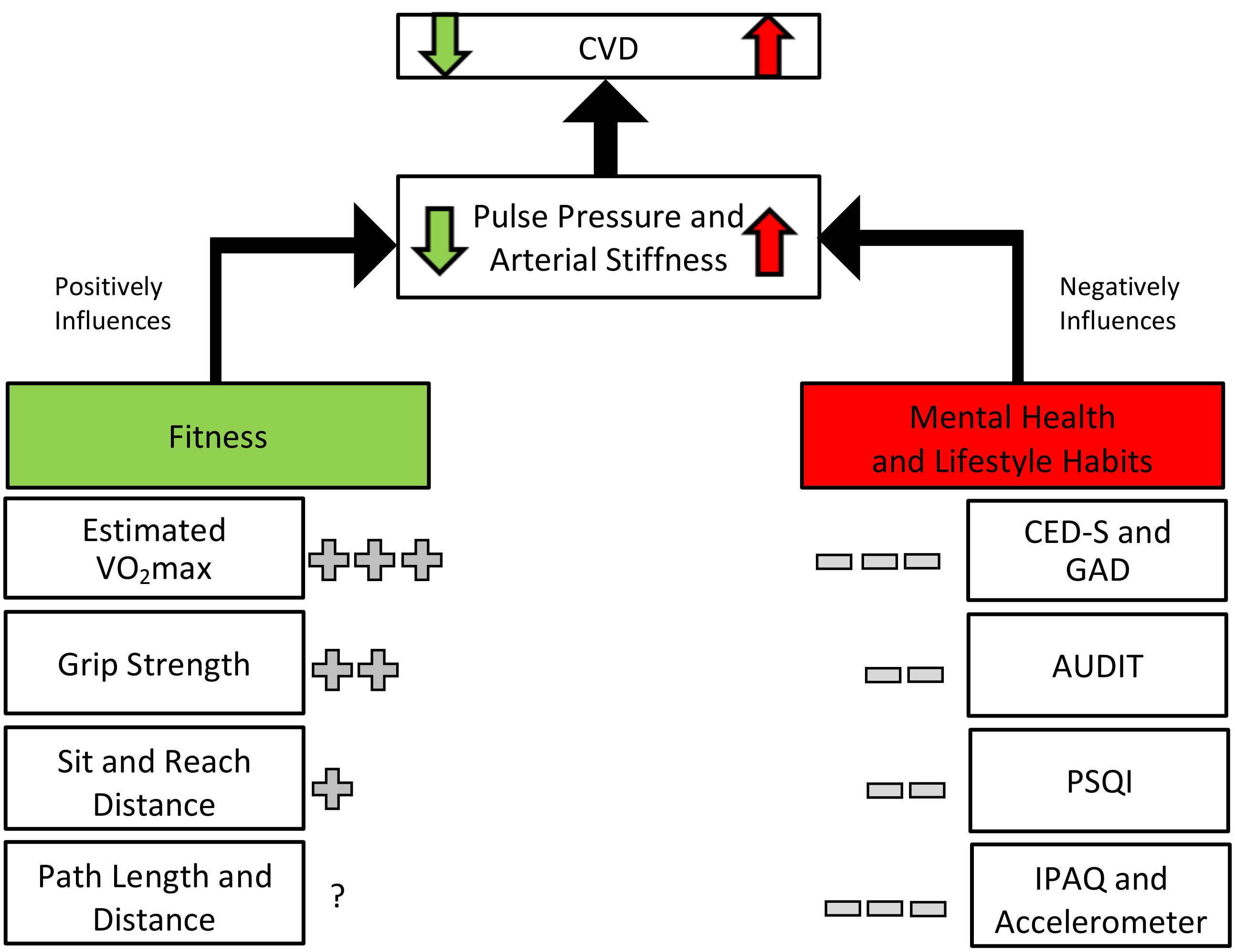
Theoretical Model - Measurements

Vascular health was measured through pulse pressure (PP) and pulse wave velocity (PWV). Vascular health is a well established indicator of CVD risk.

For the fitness measures, estimated VO_2max was primarily used as the indication of CRF, maximum and average hand grip strength was used to determine muscular strength, the furthest and average distance achieved during sit and reach was used to determine flexibility and path length and distance traveled were used to measure changes in center of pressure during balance assessments. There is strong evidence (+++) to support a positive relationship between CRF and vascular health, meaning a higher estimated VO_2max is associated with healthier vasculature assessed by lower PP and PWV. There is some evidence (++) to support an inverse relationship between strength and vascular health, meaning stronger women have lower PP and PWV. There is emerging evidence (+) which links flexibility and vascular health, showing that a more flexible person (further distances on the sit and reach test) has lower PP and PWV. There is no evidence (?) on the relationship between balance and vascular health.

For the mental health and lifestyle assessments, the Center for Epidemiological Studies Depression Scale (CES-D) was used as a measure of depression, the Generalized Anxiety

Disorder (GAD-7) survey was used as a measure of anxiety, the Alcohol Use Disorders Identification Test (AUDIT) was used to determine harmful alcohol tendencies, the Pittsburg Sleep Quality Index (PSQI) was used as the measure of sleep quality, and the International Physical Activity Questionnaire (IPAQ) and waist-worn accelerometers were used to determine physical activity and sedentary behaviors. There is moderate evidence (--) and strong (---) evidence to support negative relationship between high CES-D, GAD-7, PSQI and AUDIT scores, as well as high sedentary behavior and unhealthy vascular health indicated by high PWV and PP.



Statistical Plan

To test the above hypotheses, significance was set a priori at $p<0.05$ and all data was analyzed using IBM SPSS v. 24 (Armonk NY, USA). An analysis of variance (ANOVA) with Bonferoni post hoc analysis was used to determine differences in vascular health between the groups (Aim 1).Similarly, an ANOVA was used to compare the differences among varsity athletes, club sport athletes and RA women in mental health symptoms and lifestyle habits with Bonferoni post hoc analysis. If a group effect was found, we performed pair-wise comparisons using a t-test.

Results

40 women, eight varsity athletes (age 20 ± 1 years, BMI 24.07 [kg/m^2]), 12 club sport athletes (age 20 ± 2 years, BMI 24.46 kg/m^2) and 20 RA women (age 20 ± 2 years, BMI 24.31 kg/m^2) participated in this study. Groups were well matched for age, height and race, by design see Table 4.1. Differences in body fat did not reach statistical significance however there was a trend for the varsity athletes to have less body fat than both the club athletes and RA (varsity compared to club $p=0.052$). The breakdown of the athletes by sport is listed in Table 4.2 and relevant medication usage is listed in Table 4.3.

Table 4.1. Demographics

	Varsity (n=8)	Club (n=12)	RA (n=20)
Age (years)	20 ± 1	20 ± 2	20 ± 2
Height (meter)	1.71 ± .11	1.66 ± .05	1.68 ± .04
Weight (kg)	70.38 ± 10.99	68.03 ± 11.55	66.64 ± 8.30
BMI (kg/meter^2)	24.07 ± 1.62	24.46 ± 3.16	23.70 ± 2.95
Body Fat (%)	21.9 ± 6.5	(n=9) 31.0 ± 8.5	(n=19) 28.5 ± 6.2
Glucose (mg/dL)	92 ± 13	86 ± 4	88 ± 10
Total Cholesterol (mg/dL)	(n=7) 156 ± 29	164 ± 35	169 ± 34
LDL (mg/dL)	(n=4) 81 ± 28	(n=10) 82 ± 28	(n=17) 95 ± 26
HDL (mg/dL)	(n=7) 60 ± 22	(n=11) 67 ± 19	(n=19) 60 ± 18
Race	(n=7)		
African-American	2	2	4
America Indian or Alaska Native	0	1	0
Asian	0	1	0
Mixed Race	0	0	1
White	5	8	15

RA, recreationally active; kg, kilograms, %, percent body fat; mg, milligram; dL, deciliter.

Table 4.2. Breakdown of athletes by sport

	Varsity	Club	**TOTAL**
Basketball	0	8	8
Boxing	0	1 (same as swimming)	1
Cross Country	1	0	1
Field Hockey	0	1	1
Gymnastics	0	1	1
Rowing	2	0	2
Soccer	3	1	4
Swimming	0	1 (same as boxing)	1
Volleyball	2	0	2
TOTAL	8	12	20

Table 4.3. Relevant medication usage

	Varsity (n=7)	Club (n=12)	RA (n=20)
Contraceptive Use	2	5	7
Anxiety/Depression	0	0	3
Heart Related	0	0	1
Sleep	1	0	0
Asthma	1	0	0

Contraceptive Use, either oral contraceptive or intrauterine device; heart related, spironolactone - use not specified.

Vascular Assessment

There were no significant differences between the varsity athletes, club sport athletes and RA participants for PWV see Table 4.4. There were no significant differences in systolic, diastolic or mean blood pressure or stroke volume between the groups. Varsity athletes had significantly higher bPP compared to club athletes and RA ($p<0.05$) and higher cPP compared to RA, see Table 4.4 and Figure 4.1 and 4.2.

Table 4.4. Vascular Variables

	Varsity (n=8)	Club (n=12)	RA (n=20)
SBP (mmHg)	115 ± 10	(n=11) 111 ± 7	109 ± 8
DBP (mmHg)	69 ± 7	(n=11) 71 ± 5	70 ± 7
MAP (mmHg)	85 ± 8	85 ± 5	83 ± 7
cSBP (mmHg)	107 ± 9	104 ± 7	100 ± 7
cDBP (mmHg)	70 ± 8	72 ± 5	70 ± 7
SV (mL)	80 ± 11	75 ± 13	72 ± 10

RA, recreationally active; SBP, systolic blood pressure; DBP, diastolic blood pressure; MAP, mean arterial pressure; mmHg, millimeters of mercury; PWV, pulse wave velocity; m, meter; s, second; cSBP, central SBP; cDBP, central DBP; SV, stroke volume

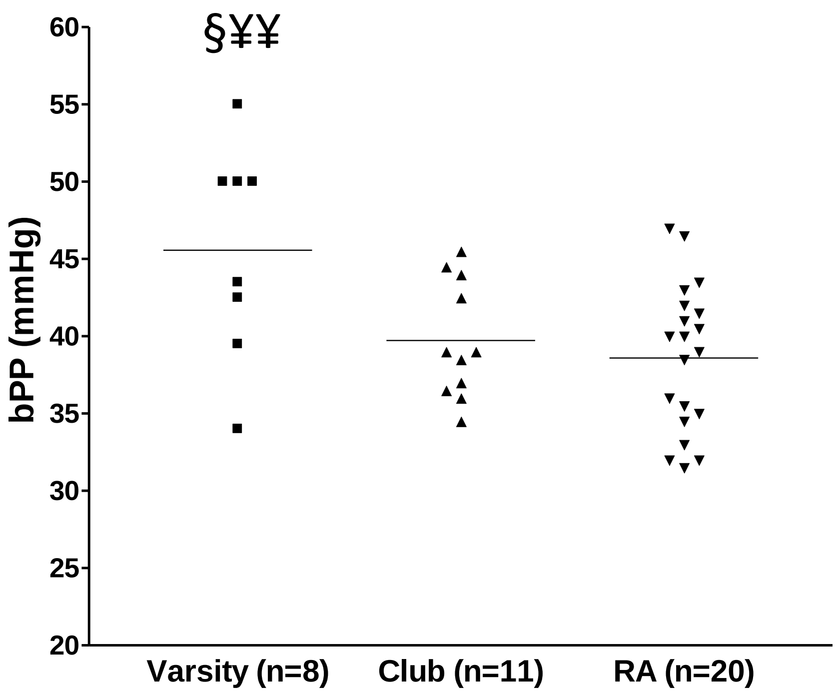


Fig 4.1. Brachial pulse pressure by group. § significantly different than Club p<0.05, ¥¥ significantly different than RA p<0.01.

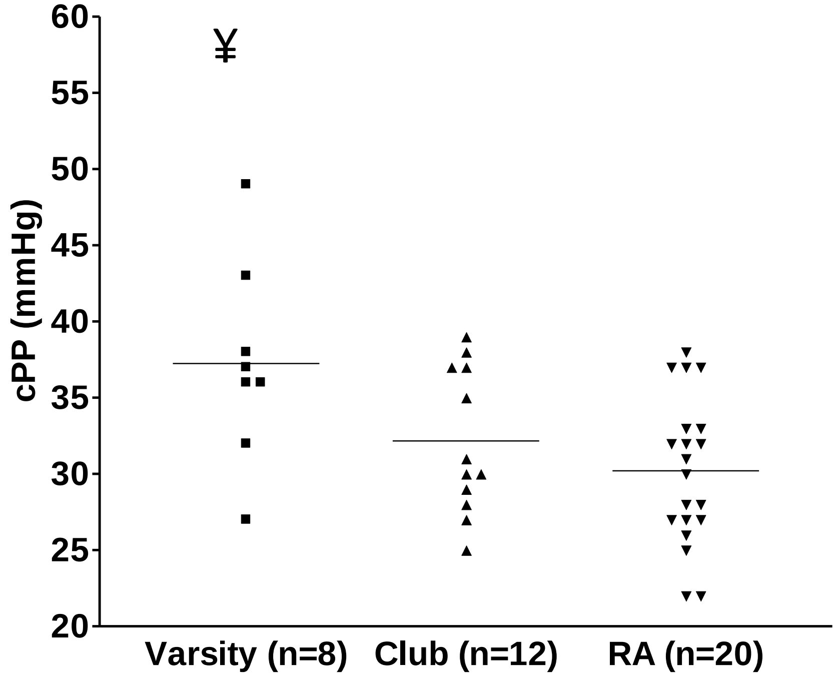


Fig 4.2. Central pulse pressure by group. ¥ significantly different than RA p<0.05.

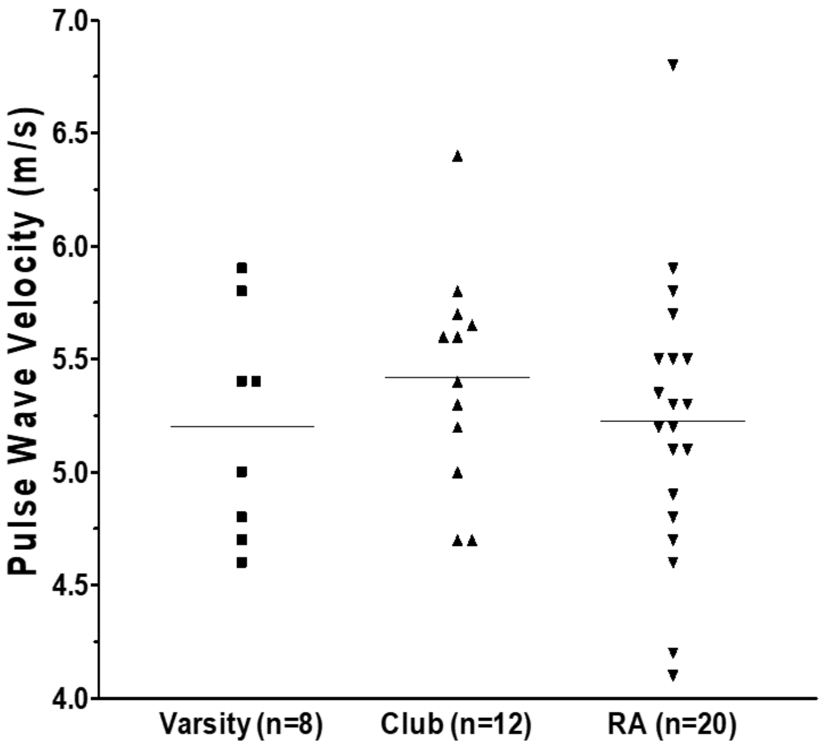


Fig 4.3. Pulse wave velocity by group. No significant differences between groups.

Fitness

The varsity athletes had greater cardiorespiratory fitness than the club sport athletes and the RA participants, indicated by lower HRpeak ($p<0.01$), HRpost ($p<0.05$) and higher estimated VO_2max ($p<0.05$), see Table 4.5.

Table 4.5. Cardiorespiratory Fitness

	Varsity (n=8)	Club (n=12)	RA (n=20)
Baseline HR (bpm)	55 ± 6	57 ± 7	62 ± 10
HRpeak (bpm)	130 ± 10 ¥¥	142 ± 12	154 ± 18
HRpost (bpm)	67 ± 10 ¥	76 ± 15	92 ± 23
Estimated VO_2max (ml/kg/min)	53.7 ± 1.9 ¥	51.7 ± 2.7	48.9 ± 4.1

HR, heart rate; bpm, beats per minute; VO_2max, maximum volume of oxygen; ml, milliliter; kg, kilogram; min, minute; ms, millisecond; %, percentage. ¥ significantly different than RA p<0.05, ¥¥ significantly different than RA p<0.01

There were no differences in maximum hand grip strength between the three groups, however, varsity athletes had significantly higher average strength than RA ($p<0.05$), see Table 4.6. There were no differences in maximum or average flexibility between the three groups, and, see Table 4.6.

Table 4.6. Strength and flexibility variables

	Varsity (n=8)	Club (n=12)	RA (n=20)
Hand Grip Max (kg)	37 ± 7	32 ± 7	31 ± 5
Hand Grip Avg (kg)	35 ± 7 ¥	30 ± 6	28 ± 5
Flexibility Max (cm)	33.8 ± 8.1	35.5 ± 8.4	36.5 ± 6.6
Flexibility Avg (cm)	32.2 ± 8.3	33.7 ± 8.2	35.3 ± 6.2

RA, recreationally active; kg, kilogram; cm, centimeter.

There were no difference in balance path length or distance traveled between the varsity, club and RA for any of the four conditions, although the varsity athletes recorded slightly better balance overall, see Table 4.7.

Table 4.7. Balance variables

	Varsity (n=8)	Club (n=12)	RA (n=20)
EOB Path Length (cm)	12 ± 3	16 ± 6	14 ± 3
ECB Path Length (cm)	17 ± 5	21 ± 6	19 ± 5
EOF Path Length (cm)	22 ± 6	26 ± 6	23 ± 4
ECF Path Length (cm)	46 ± 11	48 ± 13	47 ± 12
EOB Distance (cm)	0.26 ± .08	0.34 ± .12	0.35 ± .10
ECB Distance (cm)	0.34 ± .12	0.36 ± .07	0.40 ± .16
EOF Distance (cm)	0.57 ± .17	0.55 ± .10	0.64 ± .20
ECF Distance (cm)	0.86 ± .18	0.88 ± .18	0.97 ± .24

RA, recreationally active; EOB, eyes open on the board; cm, centimeter; ECB, eyes closed on the board; EOF, eyes open on the foam pad, ECF, eyes closed on the foam pad.

Mental Health and Lifestyle

There were no significant differences between the varsity, club and RA participants for scores of any mental health assessments or lifestyle questionnaires, see Table 4.8. Three RA women met the criteria for clinically relevant depression symptoms, indicated by a CES-D score greater than 20 (130). Nine RA participants reported higher scores on the GAD-7, including six RA reporting symptoms associated with mild (score of 5) anxiety, and overall more RA reporting moderate (score between 5 and 10) or severe (score greater than 15) anxiety symptoms (115), compared to one varsity athlete and three club athletes reporting clinically relevant anxiety symptoms. Four RA and five club sport participants met the criteria for harmful drinking behaviors (indicated by an AUDIT score greater than 8), including one RA participant classified as hazardous behavior (indicated by an AUDIT score greater than 15) (23). All groups had greater than 75% of participants report poor sleep quality, indicated by a score greater than 5 (23).

The varsity athletes spent significantly more time in vigorous activities than both the club sport ($p<0.05$) and the RA ($p<0.05$), as well as significantly less sedentary time compared to both club sport ($p<0.01$) and RA ($p<0.01$) assessed through the accelerometer, see Figure 4.3, 4.4 and 4.5.

Table 4.8. Mental Health Symptoms and Lifestyle Habits

	Varsity (n=7)	Club (n=12)	RA (n=20)
Depression Symptomology (CES-D) [# clinically relevant depression symptoms]	5.1 ± 2.7 [0]	6.8 ± 4.3 [0]	11.2 ± 9.5 [3]
Anxiety (GAD-7)	2.4 ± 1.3	2.3 ± 2.2	4.8 ± 4.6
[# mild, moderate, severe]	[1,0,0]	[1,2,0]	[6,2,1]
Alcohol Use (AUDIT)	4.4 ± 2.1	6.2 ± 3.6	4.8 ± 3.9
[# harmful]	[1]	[5]	[4]
Sleep Quality (PSQI)	7.6 ± 2.2	7.0 ± 2.1	7.8 ± 2.5
[# poor sleep quality]	[6]	[9]	[15]
Self-Reported Sleep (PSQI) (min)	462 ± 66	420 ± 78	426 ± 60
IPAQ			
Vig (MET/week)	2811 ± 2132	1160 ± 1314	970 ± 1373
Mod (MET/week)	965 ± 1141	190 ± 305	334 ± 448
Walking (min/week)	884 ± 779	1493 ± 2046	982 ± 1343
Sitting time (hour/week)	7.6 ± 1.8	9.7 ± 4.8	8.3 ± 5.8
Accelerometry			
MVPA (min/day)	68.60 ± 11.32	55.66 ± 19.92	51.67 ± 15.44

RA, recreationally active; CES-D, Center for Epidemiological Studies Depression Scale; GAD-7, Generalized Anxiety Disorder Questionnaire; AUDIT, Alcohol Use Disorders Identification Test; PSQI, Pittsburg Sleep Quality Index; IPAQ, International Physical Activity Questionnaire; Vig, time spent in vigorous; Mod, time spent in moderate; MVPA, moderate to vigorous physical activity per day; MET, metabolic equivalent; min, minute.

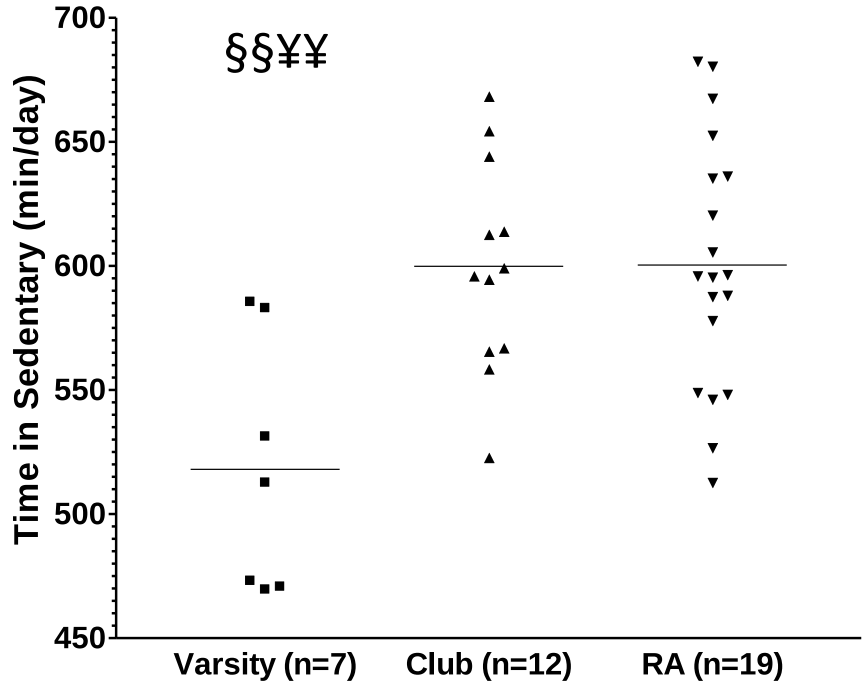


Fig 4.4. Time spent in sedentary activities assessed through accelerometer. §§ significantly different than Club p<0.01, ¥¥ significantly different than RA p<0.01.

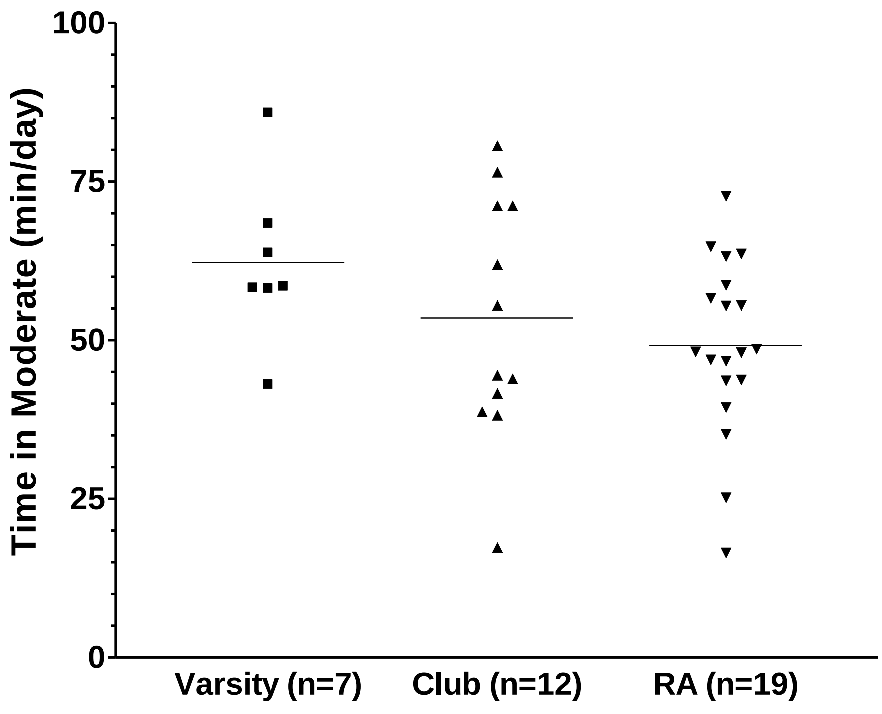


Fig 4.5. Time spent in moderate activities assessed through accelerometer.

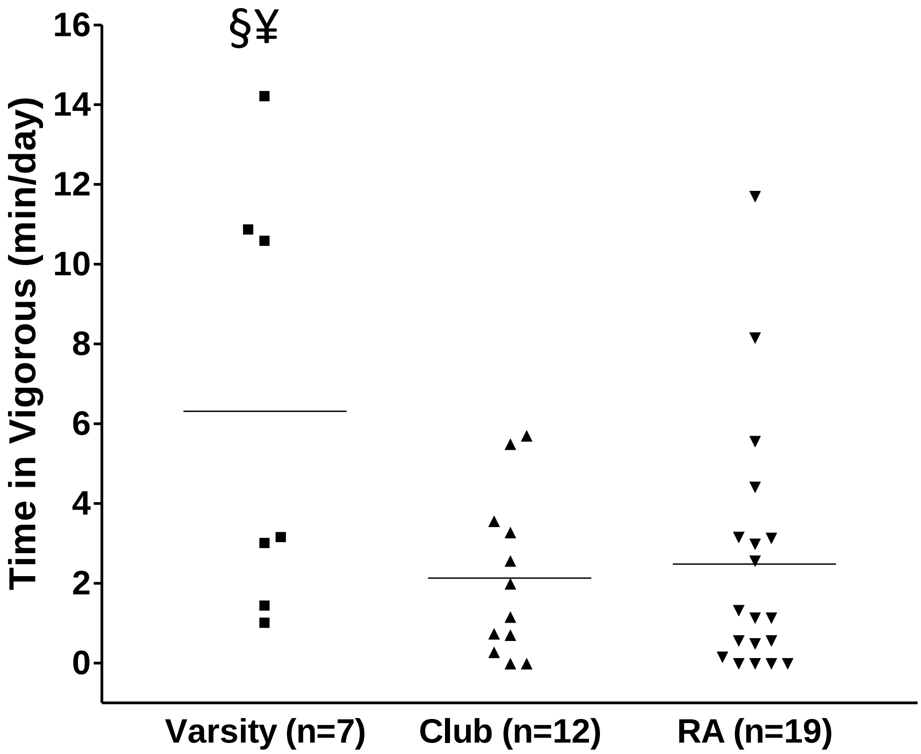


Fig 4.6. Time spent in vigorous activities assessed through accelerometer. § significantly different than Club p<0.05, ¥ significantly different than RA p<0.05.

Discussion

The purpose of this study was to investigate vascular health and mental health and in young collegiate varsity athletes, club sport athletes and RA women. Contrary to our hypothesis, there were no differences between varsity athletes and RA in vascular health assessed through arterial stiffness, however, varsity athletes had higher brachial and central pulse pressure compared to RA. Also contrary to our hypothesis, varsity athletes spent less time in sedentary and greater time in vigorous activity, as assessed through the accelerometer, compared to both club and RA ($p<0.05$). Moreover, there were no differences in mental health status or related lifestyle habits between the groups, contrary to our hypothesis.

We interpret these findings to mean female collegiate varsity athletes do not have significantly better cardiovascular health compared to club sport athletes or RA. The varsity athletes had higher pulse pressures than the club athletes and RA, but this occurred concomitant with similar levels of aortic stiffness and mean arterial pressure across groups. Thus, findings of higher PP in female athletes may reflect cardiac adaptations in athletes. Athletic competition and the stressors of balancing academic and athletic life did not negatively impact the mental health of varsity athletes, demonstrated by the lower prevalence of clinically relevant depression and anxiety symptoms assessed by survey questionnaires.

Fitness and Vascular Health

Varsity athletes had significantly higher central pulse pressure compared to RA, and higher brachial pulse pressure compared to both club sport athletes and RA. Higher PP is associated with increased CVD risk (104), therefore it was surprising to see the varsity athlete group with higher PP. However it should be noted that higher PP was seen concomitant with similar aortic stiffness and mean arterial pressure as club athletes and RA women. Previous studies in men have seen higher PP in athletes compared to non-athletes (71). It has been suggested that the increased PP is a reflection of a larger “athlete’s heart” ejecting a larger stroke volume into an elastic artery of similar size and compliance as seen in non-athletes (8). When seen in young otherwise healthy and fit adults, elevated PP in the presence of low mean arterial pressure and aortic stiffness has been suggested to be a spurious and innocuous finding (85). Previous literature supports that stroke volume (SV) has a positive relationship with pulse pressure in a young healthy population (82). While SV was not significantly greater in the varsity athletes, there was a trend of greater SV with higher fitness levels (varsity athletes with the highest, then club sport, then RA), which is in line with literature that establishes athletes are known to have an increased stroke volume compared to RA (69). Moreover, we noted a significant association between SV and brachial PP (r = 0.58, p<0.001) as well as central PP (r = 0.60, p<0.001). Thus, a larger PP in athletes may not be indicative of CVD risk but a reflection of cardiovascular adaptations secondary to their athletic training.

Additionally, pulse pressure may be amplified at lower HRs (24, 32) and our results confirm an inverse association between resting HR and brachial PP (r = -0.35, p=0.01) as well as central PP (r = -0.33, p=0.02). Although not statistically significantly, varsity athletes had lower resting HR compared to club athletes and RA women likely owing to increased parasympathetic nervous system activity (i.e. cardiac vagal modulation) from exercise training (20, 93, 103). These findings support our contention that an elevated PP in athletes is a cardiovascular adaptation secondary to higher fitness from athletic training.

There were no differences in arterial stiffness between the varsity athletes, club sport and RA. Groups were intentionally matched for age, height, and race – 3 key predictors of arterial stiffness (46, 77, 81). Groups also did not differ in other key predictors of arterial stiffness including blood lipids, glucose, BMI and body fat and none of the women smoked cigarettes (22). The present study found varsity athletes had higher cardiorespiratory fitness and less time spent in sedentary activities compared to RA; both higher fitness (36) and lower sedentary time has been shown to be related to lower arterial stiffness (52). This begs the question, why didn’t the varsity athletes have lower arterial stiffness compared to the other groups of less-fit/less active women? Perhaps healthier arterial stiffness measurements due to high fitness are only seen in an aging female population. Arterial stiffness, as well as many other traditional CVD risk factors, increases with normal aging (81, 128). Post-menopausal women have greater arterial stiffness compared to similar-aged men (29), as expected due to the known influence of cardio-protective mechanism of estrogen which is eliminated during menopause (3). It is also possible that vascular changes secondary to strength training abrogated changes seen from aerobic/endurance exercise alone.

Varsity athletes had higher average strength compared to RA. As part of athletic commitments, varsity athletes engage in routine resistance exercise seeking to increase strength and thus improve sport performance; therefore the higher reported strength was expected. The literature investigating the relationship between arterial stiffness and strength is controversial. Some cross-sectional studies, including previous findings within this laboratory, suggests an inverse relationship between strength and arterial stiffness (13, 38, 39, 59), however other studies show that strength training may increase arterial stiffness (28). Interestingly, when strength training is combined with resistance training, there is no change in arterial stiffness; that is, the benefits of a reduction in arterial stiffness from aerobic exercise are lost but the increases from resistance exercise are prevented (58). Thus in our study, women engaging in habitual endurance and strength training may not exhibit any changes arterial stiffness assessed using carotid-femoral pulse wave velocity.

The Importance of Mental Health and Lifestyle Habits for the Collegiate Athlete

Although the mental health metrics and lifestyle habits did not differ among the athletes and non-athletes nor were they associated with CVD risk, they were interrelated (supplemental Table 1). Thus our findings underscore the importance of mental health on related lifestyle habits in young, healthy women. Adults suffering from mental health concerns such as depression and anxiety may use substances such as alcohol to manage these symptoms (11), however, the use of alcohol may decrease sleep quality, potentially leading to greater anxiety about sleep habits demonstrating a bi-directional relationship (27). Our study supports this cooperative relationship based on the moderate and strong relationships between sleep quality, depression and anxiety. This emphasizes the importance of managing mental health symptoms to minimize the effects of the negative lifestyle habits.

We hypothesized the athletes would have higher prevalence of depression compared to the RA, as college life brings in new stressors for young adults in addition to the stressors of committing to an athletic team (140). Additionally, as the "fish bowl effect" described by Tricker suggests, athletes are living in highly charged, intense and publically exposed environment and are therefore highly susceptible to mental health concerns and negative lifestyle behaviors to alleviate some of those stressors (72, 124). There were no differences in the average depression symptomology scores assessed through the CES-D between the groups, nor average anxiety scores assessed through the GAD-7. However, there was a trend towards the club sport athletes and RA having higher scores than the varsity athletes for depression and anxiety symptomology. Specifically, three RA scores reached clinically relevant depression symptoms (130) and nearly half of the RA reported scores with associated with diagnosing generalized anxiety disorder, including three participants who would be classified with moderate or severe anxiety (to be confirmed with further evaluations) (115). Accordingly, three RA participants reported taking medications used to treat depression/anxiety symptoms. Research suggests that athletes use a variety of coping strategies to deal with adversity related to athletics, either during competition or during relationship management, such as the player-coach relationship (66). Outside of athletics, varsity athletes may apply similar coping strategies to deal with a stressful situation, thereby reporting less depression and anxiety, while the RA participants may not be in situations where coping mechanisms are practiced. Additionally, anxiety is seen more frequently in aesthetic sports such as gymnastics, swimming and figure skating (108). Perhaps the reason why both athlete sub-groups scored lower on both the depression and anxiety questionnaires compared to RA is due to the majority of these athletes participating in non-aesthetic sports.

We hypothesized the varsity athletes would have greater risky alcohol consumption behaviors, however greater risky drinking behavior was seen in the club athletes. Only one club athlete and one RA reported never having an alcoholic drink. Hazardous drinking behavior was most prevalent in the club sport group, with the highest average score on the AUDIT and nearly 42% of participants reporting scores indicative of harmful or hazardous drinking behavior (23). Qualitative research has shown Division 1 athletes believe their athletic schedules provide less opportunity to drink than their peers (72). Therefore, the athletic demands of the varsity athletes in the present study may inhibit alcohol consumption as frequently as they would without the team scheduled workouts. Club sport athletes may have similar drinking behaviors as the varsity athletes but substantially less time commitments, leading to increased alcohol consumption, or may not have team rules against alcohol use as suggested by Martin (72). Further, the NCAA provides resources to student athletes about effects of alcohol consumption on athletic performance and various resources about minimizing high-risk substance abuse situations (83). Club sport athletes may not realize the impact of alcohol consumption has on performance, or what constitutes high risk drinking, as this information may not be as readily available.

We hypothesized the athletes would report higher scores on the sleep assessment indicating poor sleep quality. Previous literature investigated sleep quality in Division 1 athletes and found over 42% of the athletes were identified as poor sleepers assessed through the PSQI (70). There were no statistical differences in the sleep quality scores between the three groups in the present study and prevalence of poor sleep quality was similar (86% in varsity, 75%, in club, 75% in RA). The American Academy of Sleep Medicine and the Sleep Research Society recommends adults sleep seven or more hours per night on a regular basis (135). Adults who sleep less than seven hours per night are at an increased risk for weight gain and obesity, diabetes, hypertension, heart disease/stroke and depression (25, 135). In each of the three groups, the average participant slept for more than seven hours per night, assessed through self-report measures in the PSQI. The poor sleep quality seems to come from high scores in the sleep disturbances, which may negatively influence sleep latency (amount of time it takes to fall asleep). Sleep disturbances include waking up in the middle of the night or early in the morning, being too hot or cold and not falling asleep for over 30 minutes, which is factored into the sleep latency portion of the PSQI (23). Sleep latency may be improved by maintaining good sleep hygiene guidelines as suggested by Kroshus (63).

The NCAA recently released a position paper on the importance of sleep and sleep quality for collegiate athletes (63). This paper highlights the relationship between sleep and athletic performance, likelihood of injury/illness, mental health and academic performance

(63). Additionally, the paper recommends educating athletes on the importance of sleep, including sleep screening into pre-participation exams and provides coaches with evidence-based sleep education (63). This paper was published near the end of the 2018-2019 academic year, months after data was collected in these varsity athletes (63). It would be interesting to repeat this sleep quality evaluation in the varsity athletes next year to see if the position paper has impacted collegiate varsity athlete's sleep habits and therefore improve sleep quality. Other collegiate organizations, such as residential life, Greek life and social clubs across campus should be notified of this position paper as well – as poor sleep quality is reported to be an issue across all college students in this study, despite both self-reported and qualitative assessments suggesting these college students are on average sleeping for the recommended number of hours.

Adults are encouraged to spend less time in sedentary activities due to the known adverse effects of sedentary behavior (44). Coronary heart disease (134), body size (51), metabolic syndrome, diabetes and CVD (78) are all positively associated with time spent in sedentary activity, independent of time spent in moderate-vigorous activity (51). Athletes should be wary of sedentary behavior due to the association with body fatness in elite athletes (56). When changing from a highly active state, to a sedentary state, there is a reduction of muscle and insulin sensitivity which may lead to increase adipose tissue storage and subsequent weight gain (17). When an athlete is no longer in competition season or retires completely, s/he changes from a highly active state to a sedentary state, thereby increasing the likelihood of weight gain. With high sedentary time seen in the club and RA groups, it is important to increase time spent in moderate or vigorous activities to decrease risk of CVD.

Limitations

The small sample size in each athlete group may explain why few significant differences were seen between these groups. The varsity athletes in this study are all Division 1 athletes at Syracuse University, therefore we are unable to determine if similar results would be found at a different Division 1 institution or with athletes participating at a different collegiate level. Participants were recruited through convenience sampling methods, meaning many of the participants are within the exercise science department, and therefore fairly active to begin with, conferring cardiovascular benefits. Secondly, history of high school participation in sports was not evaluated when determining the RA group. This allows the possibility that the RA group participated in high school sports and thus not considerably different than the athlete group in years of sports participation. This would explain the fairly high CRF values in the RA group.

Strengths of this study include evaluating health from a holistic perspective, with the ultimate focus of determining CVD health. College students and college student athletes are important populations to focus on due to the high prevalence of depression/anxiety and alcohol consumption. Additionally, investigating this young population allows the potential for lifestyle changes, such as increasing fitness, to positively influence CVD health later in life.

Conclusion

Female collegiate varsity athletes do not have better cardiovascular health compared to club sport athletes or non-athletes, despite having greater fitness and healthier physical activity habits and with similar prevalence of mental health symptoms. Interestingly, female collegiate varsity athletes have higher pulse pressure, conventionally viewed as a risk for CVD. However increased PP may be an adaptation due to high training loads leading to physiological adaptations of the athlete's heart coupled with training-induced bradycardia.

Appendix 1: Supplementary Data

Table S1. Correlation matrix between mental health and lifestyle habits (n=40)

	CES-D	GAD-7	AUDIT	PSQI	Sed (Accel)	Mod (Accel)	Vig (Accel)
GAD-7	0.73**						
AUDIT	-0.14	-0.13					
PSQI	0.62**	0.39*	0.01				
Sed (Accel)	0.21	0.21	-0.20	0.10			
Mod (Accel)	0.07	-0.05	-0.34*	0.13	-0.25		
Vig (Accel)	-0.15	-0.14	-0.29	-0.07	-0.38*	0.24	
Sleep (Accel)	-0.12	-0.11	0.12	-0.12	-0.76**	0.05	0.24

CES-D, Center for Epidemiological Studies Depression Scale; GAD-7, Generalized Anxiety Disorder; AUDIT, Alcohol Use Disorders Identification Test; PSQI, Pittsburg Sleep Quality Index; Vig (Accel), time spent in vigorous assessed through accelerometer; Mod (Accel), time spent in moderate assessed through accelerometer; Sleep (Accel), time spent in sleep assessed through accelerometer; * $p<0.05$, ** $p<0.01$.

Appendix 2: Informed Consent

Syracuse University IRB Approved
OCV OCT 10 2019

EXERCISE SCIENCE
COMSTOCK AVENUE 201 WOMEN'S BUILDING
SYRACUSE, NY 13210
(315)-443-2114

IMPACT OF ETHNICITY AND RACE ON CARDIOVASCULAR AND COGNITIVE FUNCTION IN YOUNG ADULTS

Principal Investigator: Kevin Heffernan, Ph.D.
Phone: 315-443-9801
Email: ksheffer@syr.edu
IRB Protocol #:

My name is Kevin Heffernan and I am an Associate Professor in Exercise Science. My research team and I are inviting you to participate in a research study. Involvement in the study is voluntary, so you may choose to participate or not to participate. This sheet will explain the study to you and please feel free to ask questions about the research if you have any. I will be happy to explain anything in detail if you wish. You will receive a copy of this consent form. If you would like more time before making a decision to participate in this research study, feel free to take this form with you as you leave. You may contact us any time with questions.

Purpose

Risk for heart disease and stroke is higher in individuals that self-identify as African American and Hispanic American compared to individuals that self-identify as White American. Reasons for differences in heart disease and stroke risk across different races and ethnicities is not fully understood. An important factor that influences a person's risk for future heart disease and stroke is artery elasticity. With aging, our arteries become less elastic. Less elastic (stiff) arteries cause high blood pressure which may place extra stress on the heart and the brain. We wish to examine artery elasticity and brain health (measured as cognitive function or the ability to complete various mental tasks successfully that require memory, attention, and reaction time) in young African American, Hispanic American and White American adults. Our hope is that by understanding the potential relationship between artery elasticity and brain health in young African American, Hispanic American and White American adults, we may be begin to understand why there are ethnic racial differences in risk for heart disease and stoke later in life.

Who can participate?

- African American, Hispanic American and White American men and women between the ages of 18-35 that do not have cardiovascular disease, diabetes, kidney disease, sickle cell disease, or mild cognitive impairment.

Do I have to participate?

- Your participation in this study is voluntary, which means you get to decide whether or not you want to participate
- Make sure that you read this entire form before making a decision and take as much time as you need.
- Feel free to ask as many questions about the study as you want. If you do not understand a term in the form, ask, and a researcher will explain it for you.
- If you decide to participate in the study you will be asked to sign a consent form.
- Do not sign the consent form until all of your questions have been answered and you understand what will happen in the study.
- Your signature means that you agree to participate in this study.
- You can ask for a copy of this form whether or not you agree to take part in the study.
- Your decision not to be in this research study will not result in any loss of benefits to which you are otherwise entitled.

Can 1 Withdraw From The study Once It Has Started?

- At any time you may remove yourself from the study without giving any reason.
- If you are a student, withdrawing from the study will not affect your grade in courses in any way.

What Can I Expect From Participating?

For this study, you will need to visit the Human Performance Laboratory twice. Each study visit will take approximately 80 minutes. You will also need to complete a series of questionnaires that ask about your health (taking approximately 40 minutes), a home blood pressure measurement protocol and wear a small activity monitor for 7 days.

Visit I

- During the first study visit, you will fill out and sign this consent form. We will have asked that you arrive to the lab for this visit after an overnight fast (no food or sugar/caffeine containing drinks for at least 10-12 hours). Blood pressure can be affected by exercise and consuming food, caffeine, or alcohol. Therefore, we will also ask you to refrain from exercising or consuming alcohol or caffeine (including caffeinated coffee, tea, soda, or energy drinks) for at least 12 hours prior to your visit. If you smoke, please refrain the morning of testing.

- We will ask that you complete a brief paper-pencil and tablet-based cognitive test to assess basic brain function.

- We will measure your height using a large ruler that is mounted against a wall. With your shoes off, we will ask you to stand upright with your back against this wall for a few moments as we measure your height. We will measure your weight using an electronic scale.

- We will estimate your body composition (percent body fat) using a BodPod that will require you to wear tight fitting, minimal clothing for greatest accuracy in estimations. You will be asked to sit quietly in a chamber that resembles a giant egg for approximately two, 60-second intervals. This machine measures your body volume to estimate body fat. The chamber does not fill with water. You will not get wet. The chamber does not change air pressure or alter the amount of air inside the space. Additionally, we will also ask that you stand on a scale to estimate your body composition (percent body fat). This scale sends a safe, low-level electrical current throughout your body to estimate body fat. You will be asked to stand quietly on the scale for approximately 30 seconds. Similar systems are sold in stores for home use and pose no risk to the general population.

- We will assess your balance using a balance platform. You will be asked to take off your shoes. You will also be asked to wear an elastic belt around your waist (over your clothes) that has an accelerometer on it and then stand on a platform. Both the platform and belt measure subtle changes in your movement. You will stand on the platform with your eyes open, eyes closed, and again while standing on a foam pillow with your eyes open and eyes closed. A member of the research team will stand close to you at all times in case you lose your balance. This test will take 10 minutes.

- We will assess your cardiorespiratory fitness by asking you to complete the YMCA step test. You will step up and down on a 12 inch step for 3-minutes. We will have a metronome which beeps to help you keep the pace. You will be asked to wear a heart rate monitor during the test. This elastic belt will go around your lower chest. We will give you directions on how to wear the belt. You will be escorted to a nearby restroom where you will be able to put the belt on in privacy. We will escort you to the restroom after the test so you can remove the belt in privacy.

- We will assess your flexibility using a sit and reach test. With your shoes still off, you will sit on a cushioned mat on the floor with your legs completely extended in front of your body. Then, with one hand on top of the other, you will slowly reach forward as far you comfortably can, and hold position of greatest reach for a couple of seconds. A member of the research team will measure how far you have reached. This will be repeated three times. This test will take 2 minutes.

- Finally, strength will be assessed using a hand dynamometer (a handle with a foam grip that can measure how hard you squeeze). In a seated position, you will be asked to squeeze the dynamometer with their dominant hand as hard as possible for five seconds. This will be repeated for a total of three trials. This test will take 2 minutes.

- You will be escorted to a restroom and asked to provide a urine sample. We will measure your kidney function by measuring how much protein is in your urine.

- You will receive $30 for completing this visit in its entirety.

- If you wish to withdraw from the study at any time you are free to do so. You will be compensated for tasks completed ($5 for blood and urine testing, $5 for BodPod, $5 for fitness tests).

- As you leave this visit, we will send you home with a blood pressure monitor and a physical activity monitor. We will ask you to wear the blood pressure monitor for the 24 hours following your visit (including during sleep). While wearing this monitor, we will ask you not to engage in exercise. Please do not wear this blood pressure monitor during water activities such as showering/bathing and swimming. This monitor includes a small box that you wear around your waist/hip that is connected to a blood pressure cuff that wraps around your upper arm. The cuff will inflate deflate every 20-minutes during the day and every 30-minutes at night to measure your blood pressure. When the cuff is inflating/deflating, do your best to stay still. We will ask that you return this monitor to the Human Performance Lab within 48 hours. If this is challenging with your schedule, please let us know. We will make arrangements to pick the device up from you somewhere on the Syracuse University Campus based on your schedule.

- You will also receive a small accelerometer (a type of pedometer) that measures how many steps you take each day and how physically active you are. You will be asked to wear this small device on a belt around your waist for 7 days. You will complete an activity log that reports when you put the monitor on and took it off. You may return the device when you come back to the lab for the second visit.

- You will receive an additional $20 for completing the 24-hour blood pressure monitoring and 7-day physical activity monitoring and returning both monitors to the human performance lab. Please take good care of the devices and do your best to return them in working order. If you lose or break the devices, you will not be responsible to pay for replacement or repairing of the device.

Online Survey

- You will be emailed a link to several questionnaires. The questionnaires will ask for a health history, depressive symptomology and anxiety, alcohol and cannabis use, physical activity status, perceived discrimination, personality and sleep quality. If any questions make you uncomfortable, you can stop at any time. The questionnaires will take approximately 40 minutes to complete. You do not have to complete the questionnaires in one sitting. You can stop and re-start any time. If you do not complete the questionnaires, you may be excluded from participating in Visit 2.

Visit 2

- Similar to this visit (Visit l) we will ask that you arrive in following an overnight fast (no food or sugar-containing drinks for 10-12 hours, no alcohol for 10-12 hours) and refrain from exercise and caffeine for at least 12 hours. We will provide you with a snack at the end of this visit.

- You will be asked to lie down on an examination table and rest for 10 minutes. Following rest, we will place a blood pressure cuff around upper arm (bicep). We will also measure your heart rate using ECG. Three electrodes (stickers) will be placed on you. One will be placed on your left shoulder, one on the lower left rib and one on the lower right rib. These stickers can be easily peeled off when the study is over. Following this, we will check blood pressure in your wrist (radial artery), neck (carotid artery), and upper leg (femoral artery). To do this, we will use a very sensitive blood pressure machine that looks like a pen with a little watch battery at the end. We will gently place this pen on top of your skin over the wrist followed by your neck and upper leg. This measurement is non-invasive (no needles no blood) and will take less than 10 minutes. From this information, we can estimate artery elasticity.

- Next, we will measure your blood flow using an ultrasound probe which is a small device (about the size of a deodorant stick) that we will set against your skin. The probe will have some gel on it to help us see clear images of the blood vessel. The ultrasound probe will be placed on your neck and upper leg to assess artery stiffness and blood flow.

- We will measure how reactive your vessels are by imaging the artery in your arm using the same ultrasound probe that we used on your neck. We will inflate a cuff around your forearm to about 200 mmHg, similar to the highest pressure used when your blood pressure is measured at the Doctor's office, for 5 minutes. We will then deflate the cuff to release your artery and measure how it responds to the release in blood flow.

- We will also measure your hemoglobin/hematocrit, cholesterol, glucose, whole-body inflammation, and blood clot factors by obtaining a few small drops of blood from your fingertip (finger prick). These tests require that you arrive hours fasted.

- After we complete these resting measures, you will complete a series of cognitive tasks that test your memory, ability to stay focused and reaction time. The tasks will be projected from a laptop to a screen above you. You will use a hand clicker to respond to questions on the monitor for approximately 12 minutes. We will also give you some math problems to solve. During these tasks, we will continue to measure and blood pressure and blood flow in your arm, leg, neck and forehead.

- Once you have completed the cognitive tasks, we will repeat the same measures from before (blood pressure, blood flow, and finger prick).

- You will receive $20 for completing this visit in its entirety.

- If you wish to withdraw from the study at any time you are free to do so. You will be compensated for tasks completed ($5 for resting vascular measures, $5 for cognitive-vascular measures).

Estimated stud timeline for participants.

Visit 1 (~ 80 min)		Visit 2 (~60 min)	
Item	Time (min)	Item	Time (min)

Consent form	15	Rest	10
Cognitive tests	20	Artery testing baseline	15
Bod Pod	10	Cognitive testing	20
Balance Testing	10	Artery testing recovery	15
Step Test	6		
Flexibility Strength	2		
Finger prick	2		
Urine test	5		
Blood Pressure cuff demo	5		
	5		

Can I be excluded from participation for any reason?

- During Visit l, you will be asked to complete a brief cognitive test to assess basic brain function. If your score indicates that you have mild cognitive impairment, you will be excluded from participation in this study and encouraged to see your healthcare provider.

- If you regularly experience any signs or symptoms that suggest you may have a medical condition, such as cardiovascular disease, diabetes, or kidney disease, and your health care provider is not aware that you are experiencing these symptoms, we will exclude you from the study and ask that you contact your health care provider.

- If you are experiencing any signs or symptoms of a serious/significant health condition at the time of consent (i.e. severe chest pain, leg pain, dizziness, feelings of heart palpitations) we will contact emergency medical services immediately and you will not be able to participate in the study.

What Benefits Can I Expect From Participating?

- A benefit from this study is helping us understand how vascular health and cognitive health are related in young African American, Hispanic American and White American adults.

- You may feel good about helping others with their research study by participating in this research study.

- You will receive information on your blood pressure, body composition, and cardiovascular health by participating in this study.

- These tests are not being used to diagnose a problem (NOT for medical clinical purposes).

These tests are for research purposes only. If you have high blood pressure, high blood sugar, high cholesterol or protein in your urine (a sign of low kidney function) we will inform you to go the university health center or go see your health care provider.

- If you do not have a healthcare provider, please see the Resource sheet that you were given. This sheet lists local clinics and healthcare resources.

Are There Any Potential Risks From Participating In This Study?

There are some risks associated with portions of this study.

- Communicating with the researcher throughout the protocol will reduce risks.
- If at any point you are uncomfortable or feel pain anywhere, please tell us immediately.
- There is some risk of discomfort with the measurement of vessel reactivity. This technique uses a blood pressure cuff inflated around the forearm to pressures around 200 mmHg. This pressure may become uncomfortable over the 5-minute duration. You may feel as though your arm is "falling asleep," and may feel a numb or tingling sensation in the hand. This feeling will subside almost immediately when the cuff is released from the forearm and does not cause permanent damage to the arm.
- When wearing the blood pressure cuff for 24-hours, the cuff will inflate every 30-min during the night. Inflation of the cuff may disrupt your sleep.
- You may experience discomfort from the finger stick to test your blood profile. This will only be done two or three times per visit and no more than that. We will use different fingers each time to reduce discomfort. If desired we can also place ice on the finger prior to the finger stick to reduce discomfort from the pinch.
- There is a small risk of infection associated with the finger stick. However, we will reduce this risk by ensuring that equipment is clean and sterile and the finger stick technician will wear lab coat, gloves, will clean the finger with alcohol swabs, and will clean the area with a disinfectant wipe afterwards. You will also be given a bandage to cover the site to prevent infection.
- While measuring your body composition, there is a risk that you may experience feelings of claustrophobia. There is a large window at face level to help minimize these feelings. You may stop the test at any point by pressing a button inside the chamber.
- You may experience muscle discomfort/soreness after the exercise tests. All tests or are very low intensity, thus discomfort should be minimal. Also, the step test will be done before the flexibility test so that you are "warmed up" prior to the flexibility test. This will also minimize muscle discomfort.
- There is a slight risk of falling during the balance test as we will ask you to stand still with your eyes closed. You will be standing on a platform that is less than 2 inches in height and a student researcher will be standing right next to you to assist you should you lose your balance. Young, healthy adults are able to regain their balance quickly so risk of falling is low.
- Given that the Human Performance Lab is in a public building operated by Campus Recreation, others will see you enter/exit the building. Also, other students that work in the lab that are not affiliated with this study may be entering/leaving the lab. Tests will be done in private areas of the lab that are walled off, but we cannot guarantee your anonymity.
- In the event of illness or physical injury resulting from taking part in this research study, medical treatment will not be compensated for. We have not set aside money to pay for related injuries. Signing this form does not waive any legal rights. You will be responsible for any costs not paid by

your insurance company. No other compensation is offered by Syracuse University. You have not waived any of your legal rights by signing this form.

- The researcher is not immune to legal subpoena about illegal activities. Although it is very unlikely, if law enforcement officials asked to see my data, I would have to give it to them.

Are There Any Costs?

- There will be no costs to you for participating in this study.

Who Can See Information About This Study?

- Results from the balance test using the belt sensor along with your age and sex will be shared with a 3rd party company (Motion Intelligence/Quadrant Biosciences — based out of Syracuse NY). Your balance data will be de-identified so that Motion Intelligence/Quadrant IRB Approve Biosciences does not know the source of the data. They will not know your name. They will only receive your balance results, age, and sex. The balance test using the belt sensor was originally designed to be used to help healthcare providers diagnose concussion in athletes. We will not be using this test to diagnose any condition. We are only using it to measure your balance (for research purposes only). Data collected may be combined with test results from other individuals and group averages used by Motion Intelligence for purposes of identifying trends in testing results, improving the effectiveness of the test, and for comparing "normal" balance data to athletes that may have sustained a concussion.
- The research records from this study will be confidential. Confidentiality means that it is our responsibility to keep any information you provide private and safe.
- You will be given a study identification number (coded numbers, known only by primary researchers) and this will be entered into all research computers used to collect your blood pressure and blood flow. Your name will not appear anywhere on these computers.
- The paperwork, results and records will be kept in a locked filing cabinet that only the researchers with training in research ethics will have access to.
- All information stored on computers requires a password access it. Only members of the research team with training in research ethics will have this password.
- The data and research record will be stored for up to 10 years.
- Your individual results will not be used in any way (we will average all results and display group averages only when presenting findings in papers and presentations)

What Are My Rights In This Study?

- If at any point you wish to withdraw yourself from the study you may.
- You do not give up any of your legal rights by participating in this study.

Who Can I Contact For Questions Or More Information?

- If there are research related injuries or if you have any questions, concerns, or complaints about this study at any time, please feel free to contact: Dr. Kevin Heffernan at ksheffer@syr.edu or call his office at 315-443-9801.

- If you have any questions about your rights as a research participant, you have questions, concerns, or complaints that you wish to address to someone other than the investigator, if you cannot reach the investigator, or have experienced research related injuries, contact the Syracuse University Institutional Review Board at 315-443-3013.

By signing below you indicate that you have read and understood this informed consent form. You are fully aware of the purpose and procedures of this study as well as the risks, discomforts, and benefits associated with the experimental protocol and that you sign this document freely and voluntarily. All of my questions have been answered, I am 18 years of age or older, and I wish to participate in this research study. I have received a copy of this consent form.

Signature of participant Date

Printed name of participant

Signature of researcher Date

Printed name of researcher

Appendix 3: Center for Epidemiologic Studies Depression Scale (CES-D)

Center for Epidemiologic Studies Depression Scale (CES-D), NIMH

Below is a list of the ways you might have felt or behaved. Please tell me how often you have felt this way during the past week.

	During the Past Week			
	Rarely or none of time (less than 1 day)	Some or a little of the time (1-2 days)	Occasionally or a moderate amount of time (3-4 days)	Most or all of the the time (5-7 days)
1. I was bothered by things that usually don't bother me.	☐	☐	☐	☐
2. I did not feel like eating; my appetite was poor.	☐	☐	☐	☐
3. I felt that I could not shake off the blues even with help from my family or friends.	☐	☐	☐	☐
4. I felt I was just as good as other people.	☐	☐	☐	☐
5. I had trouble keeping my mind on what I was doing.	☐	☐	☐	☐
6. I felt depressed.	☐	☐	☐	☐
7. I felt that everything I did was an effort.	☐	☐	☐	☐
8. I felt hopeful about the future.	☐	☐	☐	☐
9. I thought my life had been a failure.	☐	☐	☐	☐
10. I felt fearful.	☐	☐	☐	☐
11. My sleep was restless.	☐	☐	☐	☐
12. I was happy.	☐	☐	☐	☐
13. I talked less than usual.	☐	☐	☐	☐
14. I felt lonely.	☐	☐	☐	☐
15. People were unfriendly.	☐	☐	☐	☐
16. I enjoyed life.	☐	☐	☐	☐
17. I had crying spells.	☐	☐	☐	☐
18. I felt sad.	☐	☐	☐	☐
19. I felt that people dislike me.	☐	☐	☐	☐
20. I could not get "going."	☐	☐	☐	☐

SCORING: zero for answers in the first column, 1 for answers in the second column, 2 for answers in the third column, 3 for answers in the fourth column. The scoring of positive items is reversed. Possible range of scores is zero to 60, with the higher scores indicating the presence of more symptomatology.

Appendix 4: General Anxiety Disorder (GAD-7)

The Generalized Anxiety Disorder 7-Item Scale

Over the last 2 weeks, how often have you been bothered by the following problems?	**Not at all**	**Several Days**	**More than half the days**	**Nearly every day**
1. Feeling nervous, anxious, or on edge	0	1	2	3
2. Not being able to stop or control worrying	0	1	2	3
3. Worrying too much about different things	0	1	2	3
4. Trouble relaxing	0	1	2	3
5. Being so restless that it is hard to sit still	0	1	2	3
6. Becoming easily annoyed or irritable	0	1	2	3
7. Feeling afraid as if something awful might happen	0	1	2	3

Total Score: [ ] = **Add Columns** _______+ _______+_______

If you checked off any problems, how difficult have these problems made it for you to do your work, take care of things at home, or get along with other people?

Not at all _______ **Somewhat difficult** _______ **Very difficult** _______ **Extremely Difficult** _______

Interpreting the Score:

Total Score	**Interpretation**
≥10	Possible diagnosis of GAD; confirm by further evaluation
5	Mild Anxiety
10	Moderate anxiety
15	Severe anxiety

Appendix 5: Pittsburg Sleep Quality Index (PSQI)

The Pittsburgh Sleep Quality Index (PSQI)

Instructions: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions. During the past month,

1. When have you usually gone to bed? _______________
2. How long (in minutes) has it taken you to fall asleep each night? _______________
3. When have you usually gotten up in the morning? _______________
4. How many hours of actual sleep do you get at night? (This may be different than the number of hours you spend in bed) _______________

5. During the past month, how often have you had trouble sleeping because you…	Not during the past month (0)	Less than once a week (1)	Once or twice a week (2)	Three or more times week (3)
a. Cannot get to sleep within 30 minutes				
b. Wake up in the middle of the night or early morning				
c. Have to get up to use the bathroom				
d. Cannot breathe comfortably				
e. Cough or snore loudly				
f. Feel too cold				
g. Feel too hot				
h. Have bad dreams				
i. Have pain				
j. Other reason(s), please describe, including how often you have had trouble sleeping because of this reason(s):				
6. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?				
7. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?				
8. During the past month, how much of a problem has it been for you to keep up enthusiasm to get things done?				
	Very good (0)	Fairly good (1)	Fairly bad (2)	Very bad (3)
9. During the past month, how would you rate your sleep quality overall?				

Component 1	#9 Score .... C1_______
Component 2	#2 Score (≤15min=0; 16-30 min=1; 31-60 min=2, >60 min=3) + #5a Score (if sum is equal 0=0; 1-2=1; 3-4=2; 5-6=3) .... C2_______
Component 3	#4Score (>7=0; 6-7=1; 5-6=2; <5=3)................................ C3_______
Component 4	(total # of hours asleep)/(total # of hours in bed) x 100 >85%=0, 75%-84%=1, 65%-74%=2, <65%=3..................C4_______
Component 5	Sum of Scores #5b to #5j (0=0;1-9=1;10-18=2; 19-27=3) ...C5_______
Component 6	#6 Score .... C6_______
Component 7	#7 Score + #8 Score (0=0; 1-2=1; 3-4=2; 5-6=3) .... C7_______

Add the seven component scores together: **Global PSQI Score ________**

Buysse, D.J., Reynolds III, C.F., Monk, T.H., Berman, S.R., & Kupfer, D.J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Journal of Psychiatric Research, 28*(2), 193-213.

Appendix 6: Alcohol Use Disorders Identification Test (AUDIT)

AUDIT questionnaire

Please circle the answer that is correct for you

1. How often do you have a drink containing alcohol?

· Never
· Monthly or less
· 2-4 times a month
· 2-3 times a week
· 4 or more times a week

2. How many standard drinks containing alcohol do you have on a typical day when drinking?

· 1 or 2
· 3 or 4
· 5 or 6
· 7 to 9
· 10 or more

3. How often do you have six or more drinks on one occasion?

· Never
· Less than monthly
· Monthly
· Weekly
· Daily or almost daily

4. During the past year, how often have you found that you were not able to stop drinking once you had started?

· Never
· Less than monthly
· Monthly
· Weekly
· Daily or almost daily

5. During the past year, how often have you failed to do what was normally expected of you because of drinking?

· Never
· Less than monthly
· Monthly
· Weekly
· Daily or almost daily

6. During the past year, how often have you needed a drink in the morning to get yourself going after a heavy drinking session?

· Never
· Less than monthly
· Monthly
· Weekly
· Daily or almost daily

7. During the past year, how often have you had a feeling of guilt or remorse after drinking?
· Never
· Less than monthly
· Monthly
· Weekly
· Daily or almost daily

8. During the past year, have you been unable to remember what happened the night before because you had been drinking?
· Never
· Less than monthly
· Monthly
· Weekly
· Daily or almost daily

9. Have you or someone else been injured as a result of your drinking?
· No
· Yes, but not in the past year
· Yes, during the past year

10. Has a relative or friend, doctor or other health worker been concerned about your drinking or suggested you cut down?
· No
· Yes, but not in the past year
· Yes, during the past year

Scoring the AUDIT

Scores for each question range from 0 to 4, with the first response for each question (eg never) scoring 0, the second (eg less than monthly) scoring 1, the third (eg monthly) scoring 2, the fourth (eg weekly) scoring 3, and the last response (eg. daily or almost daily) scoring 4. For questions 9 and 10, which only have three responses, the scoring is 0, 2 and 4 (from left to right).

A score of 8 or more is associated with harmful or hazardous drinking, a score of 13 or more in women, and 15 or more in men, is likely to indicate alcohol dependence.

Saunders JB, Aasland OG, Babor TF et al. Development of the alcohol use disorders identification test (AUDIT): WHO collaborative project on early detection of persons with harmful alcohol consumption — II. Addiction 1993, 88: 791–803.

Appendix 7: International Physical Activity Questionnaire (IPAQ)

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

(August 2002)

SHORT LAST 7 DAYS SELF-ADMINISTERED FORMAT

FOR USE WITH YOUNG AND MIDDLE-AGED ADULTS (15-69 years)

The International Physical Activity Questionnaires (IPAQ) comprises a set of 4 questionnaires. Long (5 activity domains asked independently) and short (4 generic items) versions for use by either telephone or self-administered methods are available. The purpose of the questionnaires is to provide common instruments that can be used to obtain internationally comparable data on health–related physical activity.

Background on IPAQ

The development of an international measure for physical activity commenced in Geneva in 1998 and was followed by extensive reliability and validity testing undertaken across 12 countries (14 sites) during 2000. The final results suggest that these measures have acceptable measurement properties for use in many settings and in different languages, and are suitable for national population-based prevalence studies of participation in physical activity.

Using IPAQ

Use of the IPAQ instruments for monitoring and research purposes is encouraged. It is recommended that no changes be made to the order or wording of the questions as this will affect the psychometric properties of the instruments.

Translation from English and Cultural Adaptation

Translation from English is supported to facilitate worldwide use of IPAQ. Information on the availability of IPAQ in different languages can be obtained at www.ipaq.ki.se. If a new translation is undertaken we highly recommend using the prescribed back translation methods available on the IPAQ website. If possible please consider making your translated version of IPAQ available to others by contributing it to the IPAQ website. Further details on translation and cultural adaptation can be downloaded from the website.

Further Developments of IPAQ

International collaboration on IPAQ is on-going and an ***International Physical Activity Prevalence Study*** is in progress. For further information see the IPAQ website.

More Information

More detailed information on the IPAQ process and the research methods used in the development of IPAQ instruments is available at www.ipaq.ki.se and Booth, M.L. (2000). *Assessment of Physical Activity: An International Perspective*. Research Quarterly for Exercise and Sport, 71 (2): s114-20. Other scientific publications and presentations on the use of IPAQ are summarized on the website.

INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

   _____ days per week

   ☐ No vigorous physical activities → ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

   _____ hours per day _____ minutes per day

   ☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

   _____ days per week

   ☐ No moderate physical activities → ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

______ hours per day ______ minutes per day

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

______ days per week

☐ No walking → ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

______ hours per day ______ minutes per day

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

______ hours per day ______ minutes per day

☐ Don't know/Not sure

This is the end of the questionnaire, thank you for participating.

References

1. Leading Causes of Death in Females 2014 - Women's Health - CDC [Internet] [cited 2018 Feb 12,]. Available from: https://www.cdc.gov/women/lcod/2014/index.htm.

2. NCAA Legislative Services Database [Internet]. Available from: https://web3.ncaa.org/lsdbi/search/bylawView?id=8823.

3. Adkisson EJ, Casey DP, Beck DT, Gurovich AN, Martin JS, Braith RW. Central, peripheral and resistance arterial reactivity: fluctuates during the phases of the menstrual cycle. *Exp Biol Med (Maywood)*. 2010; 235(1):111-8.

4. Agrawal P, Mercer A, Hassanali J, Carmack C, Doss D, Murillo R. Gender Differences in the Association Between Alcohol Use and Sedentary Behavior Among Adults. *Am J Health Promot*. 2018; 32(7):1576-81.

5. Arora S, Stouffer GA, Kucharska-Newton AM, et al. Twenty Year Trends and Sex Differences in Young Adults Hospitalized With Acute Myocardial Infarction. *Circulation*. 2019; 139(8):1047-56.

6. Artero EG, Lee D, Lavie CJ, et al. Effects of muscular strength on cardiovascular risk factors and prognosis. *J Cardiopulm Rehabil Prev*. 2012; 32(6):351-8.

7. Avolio AP, Van Bortel LM, Boutouyrie P, et al. Role of pulse pressure amplification in arterial hypertension: experts' opinion and review of the data. *Hypertension*. 2009; 54(2):375-83.

8. Baggish AL, Wood MJ. Athlete's heart and cardiovascular care of the athlete: scientific and clinical update. *Circulation*. 2011; 123(23):2723-35.

9. Barreira TV, Harrington DM, Katzmarzyk PT. Cardiovascular health metrics and accelerometer-measured physical activity levels: National Health and Nutrition Examination Survey, 2003-2006. *Mayo Clin Proc*. 2014; 89(1):81-6.

10. Barreira TV, Redmond JG, Brutsaert TD, et al. Can an automated sleep detection algorithm for waist-worn accelerometry replace sleep logs? *Appl Physiol Nutr Metab*. 2018; 43(10):1027-32.

11. Bell S, Orford J, Britton A. Heavy drinking days and mental health: an exploration of the dynamic 10-year longitudinal relationship in a prospective cohort of untreated heavy drinkers. *Alcohol Clin Exp Res*. 2015; 39(4):688-96.

12. Berge HM, Isern CB, Berge E. Blood pressure and hypertension in athletes: a systematic review. *Br J Sports Med*. 2015; 49(11):716-23.

13. Bertovic DA, Waddell TK, Gatzka CD, Cameron JD, Dart AM, Kingwell BA. Muscular strength training is associated with low arterial compliance and high pulse pressure. *Hypertension*. 1999; 33(6):1385-91.

14. Beutner F, Ubrich R, Zachariae S, et al. Validation of a brief step-test protocol for estimation of peak oxygen uptake. *Eur J Prev Cardiol*. 2015; 22(4):503-12.

15. Bird M, Hill KD, Ball M, Hetherington S, Williams AD. The long-term benefits of a multi-component exercise intervention to balance and mobility in healthy older adults. *Arch Gerontol Geriatr*. 2011; 52(2):211-6.

16. Bohannon RW. Dynamometer measurements of hand-grip strength predict multiple outcomes. *Percept Mot Skills*. 2001; 93(2):323-8.

17. Booth FW, Laye MJ, Lees SJ, Rector RS, Thyfault JP. Reduced physical activity and risk of chronic disease: the biology behind the consequences. *Eur J Appl Physiol*. 2008; 102(4):381-90.

18. Borlaug, Barry A., MD|Kass, David A., MD. Ventricular–Vascular Interaction in Heart Failure. *Heart Failure Clinics*. 2008; 4(1):23-36.

19. Borrell LN. The effects of smoking and physical inactivity on advancing mortality in U.S. adults. *Ann Epidemiol*. 2014; 24(6):484-7.

20. Boutcher SH, Park Y, Dunn SL, Boutcher YN. The relationship between cardiac autonomic function and maximal oxygen uptake response to high-intensity intermittent-exercise training. *J Sports Sci*. 2013; 31(9):1024-9.

21. Brachman A, Kamieniarz A, Michalska J, Pawłowski M, Słomka KJ, Juras G. Balance Training Programs in Athletes - a Systematic Review. *J Hum Kinet*. 2017; 58:45-64.

22. Briet M, Boutouyrie P, Laurent S, London GM. Arterial stiffness and pulse pressure in CKD and ESRD. *Kidney Int*. 2012; 82(4):388-400.

23. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Res*. 1989; 28(2):193-213.

24. Cameron JD, McGrath BP, Dart AM. Use of radial artery applanation tonometry and a generalized transfer function to determine aortic pressure augmentation in subjects with treated hypertension. *J Am Coll Cardiol*. 1998; 32(5):1214-20.

25. Cappuccio FP, Cooper D, D'Elia L, Strazzullo P, Miller MA. Sleep duration predicts cardiovascular outcomes: a systematic review and meta-analysis of prospective studies. *Eur Heart J*. 2011; 32(12):1484-92.

26. Chouchou F, Pichot V, Celle S, Barthélémy JC, Gosse P, Roche F. Sleep disruptions increase arterial stiffness. *Int J Cardiol*. 2016; 203:744-5.

27. Chueh K, Guilleminault C, Lin C. Alcohol Consumption as a Moderator of Anxiety and Sleep Quality. *J Nurs Res*. 2018.

28. Cortez-Cooper MY, DeVan AE, Anton MM, et al. Effects of high intensity resistance training on arterial stiffness and wave reflection in women. *Am J Hypertens*. 2005; 18(7):930-4.

29. Coutinho T. Arterial stiffness and its clinical implications in women. *Can J Cardiol*. 2014; 30(7):756-64.

30. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. *Med Sci Sports Exerc*. 2003; 35(8):1381-95.

31. Cronin J, Lawton T, Harris N, Kilding A, McMaster DT. A Brief Review of Handgrip Strength and Sport Performance. *J Strength Cond Res*. 2017; 31(11):3187-217.

32. Dart AM, Kingwell BA. Pulse pressure--a review of mechanisms and clinical relevance. *J Am Coll Cardiol*. 2001; 37(4):975-84.

33. deGoma EM, Knowles JW, Angeli F, Budoff MJ, Rader DJ. The evolution and refinement of traditional risk factors for cardiovascular disease. *Cardiol Rev*. 2012; 20(3):118-29.

34. Physical Activity

Guidelines for Americans [Internet]. Available from: https://health.gov/paguidelines/second-edition/pdf/Physical_Activity_Guidelines_2nd_edition.pdf.

35. DuPrey KM, Liu K, Cronholm PF, et al. Baseline Time to Stabilization Identifies Anterior Cruciate Ligament Rupture Risk in Collegiate Athletes. *Am J Sports Med*. 2016; 44(6):1487-91.

36. Eriksen L, Grønbaek M, Helge JW, Tolstrup JS. Cardiorespiratory fitness in 16 025 adults aged 18-91 years and associations with physical activity and sitting time. *Scand J Med Sci Sports*. 2016; 26(12):1435-43.

37. Esser MB, Hedden SL, Kanny D, Brewer RD, Gfroerer JC, Naimi TS. Prevalence of alcohol dependence among US adult drinkers, 2009-2011. *Prev Chronic Dis*. 2014; 11:E206.

38. Fahs CA, Thiebaud RS, Rossow LM, Loenneke JP, Bemben DA, Bemben MG. Relationships between central arterial stiffness, lean body mass, and absolute and relative strength in young and older men and women. *Clin Physiol Funct Imaging*. 2018; 38(4):676-80.

39. Fahs CA, Heffernan KS, Ranadive S, Jae SY, Fernhall B. Muscular Strength is Inversely Associated with Aortic Stiffness in Young Men. *Medicine & Science in Sports & Exercise*. 2010; 42(9):1619–1624.

40. Fergusson DM, Horwood LJ, Ridder EM, Beautrais AL. Subthreshold depression in adolescence and mental health outcomes in adulthood. *Arch Gen Psychiatry*. 2005; 62(1):66-72.

41. Fields DA, Goran MI, McCrory MA. Body-composition assessment via air-displacement plethysmography in adults and children: a review. *Am J Clin Nutr*. 2002; 75(3):453-67.

42. Gando Y, Murakami H, Kawakami R, et al. Cardiorespiratory Fitness Suppresses Age-Related Arterial Stiffening in Healthy Adults: A 2-Year Longitudinal Observational Study. *J Clin Hypertens (Greenwich)*. 2016; 18(4):292-8.

43. Garatachea N, Santos-Lozano A, Sanchis-Gomar F, et al. Elite athletes live longer than the general population: a meta-analysis. *Mayo Clin Proc*. 2014; 89(9):1195-200.

44. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011; 43(7):1334-59.

45. García Pallarés J, López-Gullón JM, Torres-Bonete MD, Izquierdo M. Physical fitness factors to predict female Olympic wrestling performance and sex differences. *J Strength Cond Res*. 2012; 26(3):794-803.

46. Gatzka CD, Kingwell BA, Cameron JD, et al. Gender differences in the timing of arterial wave reflection beyond differences in body height. *J Hypertens*. 2001; 19(12):2197-203.

47. Goble DJ, Baweja HS. Postural sway normative data across the adult lifespan: Results from 6280 individuals on the Balance Tracking System balance test. *Geriatr Gerontol Int*. 2018; 18(8):1225-9.

48. Goel S, Sharma A, Garg A. Effect of Alcohol Consumption on Cardiovascular Health. *Curr Cardiol Rep*. 2018; 20(4):19.

49. Grant BF, Chou SP, Saha TD, et al. Prevalence of 12-Month Alcohol Use, High-Risk Drinking, and DSM-IV Alcohol Use Disorder in the United States, 2001-2002 to 2012-2013: Results From the National Epidemiologic Survey on Alcohol and Related Conditions. *JAMA Psychiatry*. 2017; 74(9):911-23.

50. Hassan AN. Patients With Alcohol Use Disorder Co-Occurring With Depression and Anxiety Symptoms: Diagnostic and Treatment Initiation Recommendations. *J Clin Psychiatry*. 2018; 79(1).

51. Healy GN, Wijndaele K, Dunstan DW, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care*. 2008; 31(2):369-71.

52. Heffernan KS, Tarzia BJ, Kasprowicz AG, Lefferts WK, Hatanaka M, Jae SY. Self-reported sitting time is associated with higher pressure from wave reflections independent of physical activity levels in healthy young adults. *Am J Hypertens*. 2013; 26(8):1017-23.

53. Hiles SA, Lamers F, Milaneschi Y, Penninx, B. W. J. H. Sit, step, sweat: longitudinal associations between physical activity patterns, anxiety and depression. *Psychol Med*. 2017; 47(8):1466-77.

54. Holt LE, Pelham TW, Burke DG. Modifications to the Standard Sit-and-Reach Flexibility Protocol. *J Athl Train*. 1999; 34(1):43-7.

55. Howell DR, Hanson E, Sugimoto D, Stracciolini A, Meehan WP. Assessment of the Postural Stability of Female and Male Athletes. *Clin J Sport Med*. 2017; 27(5):444-9.

56. Júdice PB, Silva AM, Magalhães JP, Matias CN, Sardinha LB. Sedentary behaviour and adiposity in elite athletes. *J Sports Sci*. 2014; 32(19):1760-7.

57. Kasch FW, Phillips WH, Ross WD, Carter JE, Boyer JL. A comparison of maximal oxygen uptake by treadmill and step-test procedures. *J Appl Physiol*. 1966; 21(4):1387-8.

58. Kawano H, Tanaka H, Miyachi M. Resistance training and arterial compliance: keeping the benefits while minimizing the stiffening. *J Hypertens*. 2006; 24(9):1753-9.

59. Keller AP, Lefferts WK, Augustine JA, Deblois JP, Heffernan KS. Muscular Strength is Inversely Associated with Central Hemodynamic Load in Young Women. *International Journal of Exercise Science*; 6(9).

60. Ko DT, Wijeysundera HC, Udell JA, et al. Traditional cardiovascular risk factors and the presence of obstructive coronary artery disease in men and women. *Can J Cardiol*. 2014; 30(7):820-6.

61. Kontro TK, Sarna S, Kaprio J, Kujala UM. Use of Alcohol and Alcohol-Related Morbidity in Finnish Former Elite Athletes. *Med Sci Sports Exerc*. 2017; 49(3):492-9.

62. Koshiba H, Maeshima E, Okumura Y. The relationship between arterial stiffness and the lifestyle habits of female athletes after retiring from competitive sports: a prospective study. *Clin Physiol Funct Imaging*. 2017; 37(5):474-80.

63. Kroshus E, Wagner J, Wyrick D, et al. Wake up call for collegiate athlete sleep: narrative review and consensus recommendations from the NCAA Interassociation Task Force on Sleep and Wellness. *Br J Sports Med*. 2019; 53(12):731-6.

64. Kyrou I, Kollia N, Panagiotakos D, et al. Association of depression and anxiety status with 10-year cardiovascular disease incidence among apparently healthy Greek adults: The ATTICA Study. *Eur J Prev Cardiol*. 2017; 24(2):145-52.

65. Lemez S, Baker J. Do Elite Athletes Live Longer? A Systematic Review of Mortality and Longevity in Elite Athletes. *Sports Med Open*. 2015; 1(1):16.

66. Leprince C, D'Arripe-Longueville F, Doron J. Coping in Teams: Exploring Athletes' Communal Coping Strategies to Deal With Shared Stressors. *Front Psychol*. 2018; 9:1908.

67. Liu H, Yuan W, Qin K, Hou J. Acute effect of cycling intervention on carotid arterial hemodynamics: basketball athletes versus sedentary controls. *Biomed Eng Online*. 2015; 14 Suppl 1:S17.

68. Liu K, Daviglus ML, Loria CM, et al. Healthy lifestyle through young adulthood and the presence of low cardiovascular disease risk profile in middle age: the Coronary Artery Risk Development in (Young) Adults (CARDIA) study. *Circulation*. 2012; 125(8):996-1004.

69. Lovic D, Narayan P, Pittaras A, Faselis C, Doumas M, Kokkinos P. Left ventricular hypertrophy in athletes and hypertensive patients. *J Clin Hypertens (Greenwich)*. 2017; 19(4):413-7.

70. Mah CD, Kezirian EJ, Marcello BM, Dement WC. Poor sleep quality and insufficient sleep of a collegiate student-athlete population. *Sleep Health*. 2018; 4(3):251-7.

71. Mahmud A, Feely J. Spurious systolic hypertension of youth: fit young men with elastic arteries. *Am J Hypertens*. 2003; 16(3):229-32.

72. Martin M. The Use of Alcohol Among NCAA Division I Female College Basketball, Softball, and Volleyball Athletes. *J Athl Train*. 1998; 33(2):163-7.

73. Mattace-Raso FUS, van der Cammen, Tischa J. M., Hofman A, et al. Arterial stiffness and risk of coronary heart disease and stroke: the Rotterdam Study. *Circulation*. 2006; 113(5):657-63.

74. McArdle WD, Katch FI, Pechar GS, Jacobson L, Ruck S. Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. *Med Sci Sports*. 1972; 4(4):182-6.

75. Miller L, Buttell FP. Are NCAA Division I Athletes Prepared for End-of-Athletic-Career Transition? A Literature Review. *J Evid Inf Soc Work*. 2018; 15(1):52-70.

76. Mitchell GF, Parise H, Benjamin EJ, et al. Changes in arterial stiffness and wave reflection with advancing age in healthy men and women: the Framingham Heart Study. *Hypertension*. 2004; 43(6):1239-45.

77. Morris LE, Flück D, Ainslie PN, McManus AM. Cerebrovascular and ventilatory responses to acute normobaric hypoxia in girls and women. *Physiol Rep*. 2017; 5(15).

78. Mosca L, Appel LJ, Benjamin EJ, et al. Evidence-based guidelines for cardiovascular disease prevention in women. *Circulation*. 2004; 109(5):672-93.

79. Munir S, Guilcher A, Kamalesh T, et al. Peripheral augmentation index defines the relationship between central and peripheral pulse pressure. *Hypertension*. 2008; 51(1):112-8.

80. Muñoz L, Norgan G, Rauschhuber M, et al. An exploratory study of cardiac health in college athletes. *Appl Nurs Res*. 2009; 22(4):228-35.

81. Najjar SS, Scuteri A, Lakatta EG. Arterial aging: is it an immutable cardiovascular risk factor? *Hypertension*. 2005; 46(3):454-62.

82. Nakagomi A, Okada S, Funabashi N, Kobayashi Y. Age-related change in contribution of stroke volume to central pulse pressure. *Clin Exp Hypertens*. 2017; 39(3):284-9.

83. Alcohol and Other Recreational Drug Prevention [Internet]. Available from: http://www.ncaa.org/sites/default/files/SSI_Substance%20Use%20Infographic_20170725.pdf.

84. National Institute of Mental Health - Major Depression Statistics [Internet]. Available from: https://www.nimh.nih.gov/health/statistics/major-depression.shtml.

85. National Institutes of Mental Health - Anxiety Disorder Statistics [Internet]. Available from: https://www.nimh.nih.gov/health/statistics/any-anxiety-disorder.shtml.

86. NCAA Demographics Database [Internet] [cited 2019 4/24/]. Available from: http://www.ncaa.org/about/resources/research/ncaa-demographics-database.

87. Nichols WW, Edwards DG. Arterial elastance and wave reflection augmentation of systolic blood pressure: deleterious effects and implications for therapy. *J Cardiovasc Pharmacol Ther*. 2001; 6(1):5-21.

88. Nishiwaki M, Kurobe K, Kiuchi A, Nakamura T, Matsumoto N. Sex differences in flexibility-arterial stiffness relationship and its application for diagnosis of arterial stiffening: a cross-sectional observational study. *PLoS ONE*. 2014; 9(11):e113646.

89. O'Connor SM, Baweja HS, Goble DJ. Validating the BTrackS Balance Plate as a low cost alternative for the measurement of sway-induced center of pressure. *J Biomech*. 2016; 49(16):4142-5.

90. O'Neill D, Britton A, Brunner EJ, Bell S. Twenty-Five-Year Alcohol Consumption Trajectories and Their Association With Arterial Aging: A Prospective Cohort Study. *J Am Heart Assoc*. 2017; 6(2).

91. O'Rourke MF, Gallagher DE. Pulse wave analysis. *J Hypertens Suppl*. 1996; 14(5):147.

92. Owen N, Healy GN, Matthews CE, Dunstan DW. Too much sitting: the population health science of sedentary behavior. *Exerc Sport Sci Rev*. 2010; 38(3):105-13.

93. Palma J, Benarroch EE. Neural control of the heart: recent concepts and clinical correlations. *Neurology*. 2014; 83(3):261-71.

94. Pescatello LS, Franklin BA, Fagard R, Farquhar WB, Kelley GA, Ray CA. American College of Sports Medicine position stand. Exercise and hypertension. *Med Sci Sports Exerc*. 2004; 36(3):533-53.

95. Peterson BJ, Fitzgerald JS, Dietz CC, et al. Division I Hockey Players Generate More Power Than Division III Players During on- and Off-Ice Performance Tests. *J Strength Cond Res*. 2015; 29(5):1191-6.

96. Pichler G, Martinez F, Vicente A, Solaz E, Calaforra O, Redon J. Pulse pressure amplification and its determinants. *Blood Press*. 2016; 25(1):21-7.

97. Pietrzak RH, Kinley J, Afifi TO, Enns MW, Fawcett J, Sareen J. Subsyndromal depression in the United States: prevalence, course, and risk for incident psychiatric outcomes. *Psychol Med*. 2013; 43(7):1401-14.

98. Reifsteck E, Brooks D, Gill D. *Moving on!: A Physical Activity Transition Program for Student-Athletes*; 2016. 1 p.

99. Riebe D, Franklin BA, Thompson PD, et al. Updating ACSM's Recommendations for Exercise Preparticipation Health Screening. *Med Sci Sports Exerc*. 2015; 47(11):2473-9.

100. Roger VL, Go AS, Lloyd-Jones DM, et al. Heart disease and stroke statistics--2012 update: a report from the American Heart Association. *Circulation*. 2012; 125(1):e-e220.

101. Rosengren A, Hawken S, Ounpuu S, et al. Association of psychosocial risk factors with risk of acute myocardial infarction in 11119 cases and 13648 controls from 52 countries (the INTERHEART study): case-control study. *Lancet*. 2004; 364(9438):953-62.

102. Russ TC, Stamatakis E, Hamer M, Starr JM, Kivimäki M, Batty GD. Association between psychological distress and mortality: individual participant pooled analysis of 10 prospective cohort studies. *BMJ*. 2012; 345:e4933.

103. Sacknoff DM, Gleim GW, Stachenfeld N, Coplan NL. Effect of athletic training on heart rate variability. *Am Heart J*. 1994; 127(5):1275-8.

104. Safar ME. Systolic blood pressure, pulse pressure and arterial stiffness as cardiovascular risk factors. *Curr Opin Nephrol Hypertens*. 2001; 10(2):257-61.

105. Safar ME, Nilsson PM, Blacher J, Mimran A. Pulse pressure, arterial stiffness, and end-organ damage. *Curr Hypertens Rep*. 2012; 14(4):339-44.

106. Sampson UK, Fazio S, Linton MF. Residual cardiovascular risk despite optimal LDL cholesterol reduction with statins: the evidence, etiology, and therapeutic challenges. *Curr Atheroscler Rep*. 2012; 14(1):1-10.

107. Saunders JB, Aasland OG, Babor TF, de la Fuente, J. R., Grant M. Development of the Alcohol Use Disorders Identification Test (AUDIT): WHO Collaborative Project on Early Detection of Persons with Harmful Alcohol Consumption--II. *Addiction*. 1993; 88(6):791-804.

108. Schaal K, Tafflet M, Nassif H, et al. Psychological balance in high level athletes: gender-based differences and sport-specific patterns. *PLoS ONE*. 2011; 6(5):e19007.

109. Schulberg HC, Saul M, McClelland M, Ganguli M, Christy W, Frank R. Assessing depression in primary medical and psychiatric practices. *Arch Gen Psychiatry*. 1985; 42(12):1164-70.

110. Seldenrijk A, van Hout, Hein P. J., van Marwijk, Harm W. J., et al. Depression, anxiety, and arterial stiffness. *Biol Psychiatry*. 2011; 69(8):795-803.

111. Shah RV, Murthy VL, Colangelo LA, et al. Association of Fitness in Young Adulthood With Survival and Cardiovascular Risk: The Coronary Artery Risk Development in Young Adults (CARDIA) Study. *JAMA Intern Med*. 2016; 176(1):87-95.

112. Shiroma EJ, Cook NR, Manson JE, et al. Strength Training and the Risk of Type 2 Diabetes and Cardiovascular Disease. *Med Sci Sports Exerc*. 2017; 49(1):40-6.

113. Skurnick JH, Aladjem M, Aviv A. Sex differences in pulse pressure trends with age are cross-cultural. *Hypertension*. 2010; 55(1):40-7.

114. Sperlich B, Becker M, Hotho A, et al. Sedentary Behavior among National Elite Rowers during Off-Training-A Pilot Study. *Front Physiol*. 2017; 8:655.

115. Spitzer RL, Kroenke K, Williams JBW, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med*. 2006; 166(10):1092-7.

116. Suchomel TJ, Nimphius S, Stone MH. The Importance of Muscular Strength in Athletic Performance. *Sports Med*. 2016; 46(10):1419-49.

117. Sugawara J, Murakami H, Maeda S, Kuno S, Matsuda M. Change in post-exercise vagal reactivation with exercise training and detraining in young men. *Eur J Appl Physiol*. 2001; 85(3-4):259-63.

118. Tanasescu M, Leitzmann MF, Rimm EB, Willett WC, Stampfer MJ, Hu FB. Exercise type and intensity in relation to coronary heart disease in men. *JAMA*. 2002; 288(16):1994-2000.

119. Tarumi T, Gonzales MM, Fallow B, et al. Central artery stiffness, neuropsychological function, and cerebral perfusion in sedentary and endurance-trained middle-aged adults. *J Hypertens*. 2013; 31(12):2400-9.

120. Thompson PD. Exercise and physical activity in the prevention and treatment of atherosclerotic cardiovascular disease. *Arterioscler Thromb Vasc Biol*. 2003; 23(8):1319-21.

121. Tomoto T, Maeda S, Sugawara J. Relation between arterial stiffness and aerobic capacity: Importance of proximal aortic stiffness. *Eur J Sport Sci*. 2017; 17(5):571-5.

122. Townsend RR, Wilkinson IB, Schiffrin EL, et al. Recommendations for Improving and Standardizing Vascular Research on Arterial Stiffness: A Scientific Statement From the American Heart Association. *Hypertension*. 2015; 66(3):698-722.

123. Trasande L, Urbina EM, Khoder M, et al. Polycyclic aromatic hydrocarbons, brachial artery distensibility and blood pressure among children residing near an oil refinery. *Environ Res*. 2015; 136:133-40.

124. Tricker R, Cook Dl. *Athletes at Risk: Drugs and Sport.* Dubuque, Iowa;: W.C. Brown; 1990.

125. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008; 40(1):181-8.

126. Title IX of the Education Amendments Act of 1972 [Internet]. Available from: https://www2.ed.gov/about/offices/list/ocr/docs/tix_dis.html.

127. US Department of Health and Human Services. NIAAA Council Approves Definition of Binge Drinking. *NIAAA Newsletter*. 2004: p. 3.

128. Vaitkevicius PV, Fleg JL, Engel JH, et al. Effects of age and aerobic capacity on arterial stiffness in healthy adults. *Circulation*. 1993; 88(4 Pt 1):1456-62.

129. Verma AK, Garg A, Xu D, et al. Skeletal Muscle Pump Drives Control of Cardiovascular and Postural Systems. *Sci Rep*. 2017; 7:45301.

130. Vilagut G, Forero CG, Barbaglia G, Alonso J. Screening for Depression in the General Population with the Center for Epidemiologic Studies Depression (CES-D): A Systematic Review with Meta-Analysis. *PLoS ONE*. 2016; 11(5):e0155431.

131. Vlachopoulos C, Aznaouridis K, O'Rourke MF, Safar ME, Baou K, Stefanadis C. Prediction of cardiovascular events and all-cause mortality with central haemodynamics: a systematic review and meta-analysis. *Eur Heart J*. 2010; 31(15):1865-71.

132. Wagner H, Pfusterschmied J, Tilp M, Landlinger J, von Duvillard SP, Müller E. Upper-body kinematics in team-handball throw, tennis serve, and volleyball spike. *Scand J Med Sci Sports*. 2014; 24(2):345-54.

133. Wakabayashi I. Age-dependent association of alcohol drinking with pulse pressure. *J Hypertens*. 2007; 25(5):971-5.

134. Warren TY, Barry V, Hooker SP, Sui X, Church TS, Blair SN. Sedentary behaviors increase risk of cardiovascular disease mortality in men. *Med Sci Sports Exerc*. 2010; 42(5):879-85.

135. Watson NF, Badr MS, Belenky G, et al. Recommended Amount of Sleep for a Healthy Adult: A Joint Consensus Statement of the American Academy of Sleep Medicine and Sleep Research Society. *Sleep*. 2015; 38(6):843-4.

136. Weiler R, Aggio D, Hamer M, Taylor T, Kumar B. Sedentary behaviour among elite professional footballers: health and performance implications. *BMJ Open Sport Exerc Med*. 2015; 1(1):e000023.

137. Wolanin A, Hong E, Marks D, Panchoo K, Gross M. Prevalence of clinically elevated depressive symptoms in college athletes and differences by gender and sport. *Br J Sports Med*. 2016; 50(3):167-71.

138. Xu D, Verma AK, Garg A, et al. Significant role of the cardiopostural interaction in blood pressure regulation during standing. *Am J Physiol Heart Circ Physiol*. 2017; 313(3):H56-H577.

139. Yamamoto K, Kawano H, Gando Y, et al. Poor trunk flexibility is associated with arterial stiffening. *Am J Physiol Heart Circ Physiol*. 2009; 297(4):1314.

140. Yang J, Peek-Asa C, Corlette JD, Cheng G, Foster DT, Albright J. Prevalence of and risk factors associated with symptoms of depression in competitive collegiate student athletes. *Clin J Sport Med*. 2007; 17(6):481-7.

141. Yeragani VK, Tancer M, Seema KP, Josyula K, Desai N. Increased pulse-wave velocity in patients with anxiety: implications for autonomic dysfunction. *J Psychosom Res*. 2006; 61(1):25-31.

CURRICULUM VITAE

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Education

2019 — Masters of Science, Exercise Science
Syracuse University, Syracuse, New York
Advisor: Kevin Heffernan
Thesis: The relationship between vascular health, fitness, mental health and lifestyle habits among female athletes and non-athletes

2015 — Bachelors of Science, Health and Exercise Sciences
Skidmore College, Saratoga Springs, NY
Thesis: The Mechanoreflex Response to Dynamic and Passive Limb Movement

Teaching Experience

09/2017 – 05/2019 — Teaching Assistant, Department of Exercise Science Syracuse University. Syracuse, NY
Structural Kinesiology for Athletic Injury Prevention
Introduction to Exercise Science

01/2014 – 05/2015 — Teaching Assistant, Department of Health and Exercise Sciences, Skidmore College. Saratoga Springs, NY
Exercise Testing and Prescription

Research Experience

09/2017 – Present — Researcher - Human Performance Laboratory, Department of Exercise Science, Syracuse University. Syracuse, NY
The Relationship between Artery Stiffness, Blood Pressure, and Muscular Strength in Women
Impact of Ethnicity and Race on Cardiovascular and Cognitive Function in Young Adults

06/2015 – 07/2017 — Senior Clinical Trials Assistant - New York University Langone Medical Center. New York, NY
"ISCHEMIA"- International Study of Comparative Health Effectiveness with Medical and Invasive Approaches

09/2013 – 05/2013 Student Researcher - Department of Health and Exercise Sciences, Skidmore College. Saratoga Springs, NY

PRISE Protocol: Protein, Resistance, Interval, Stretching, Endurance

Resistant starch effects on resting energy expenditure and associated hunger factors

The effects of a controlled high protein, low caloric diet on weight loss

Manuscripts in Review

- Heffernan KS, Columna L, Prieto L, **Keller AP**, Pagan P, DeBlois JP, Prawl A, Revolledo G, Russo N, Barreira TV. Home blood pressure assessment in children with autism spectrum disorder: A feasibility study. *Research in Developmental Disabilities*; in review
- Lefferts WL, DeBlois JP, Augustine JA, **Keller AP**, Heffernan KS. Biological and vascular contributors to cerebral pulsatility and pulsatile dampening. *Hypertension;* in review

National Presentations *Slide presentation

- *** Keller AP,** Lefferts WL, Augustine JA, DeBlois JP, Wang Q, Heffernan KS. The Relationship between Body Mass Index and Aortic Stiffness in Females across the Lifespan. American College of Sports Medicine's 66th Annual Meeting, Orlando, FL, May 28 - May 31 2019
- *** Keller AP,** Lefferts WL, Augustine JA, DeBlois JP, Heffernan KS. Muscular Strength is Inversely Associated with Central Hemodynamic Load in Young Women, American College of Sports Medicine's 65th Annual Meeting, Minneapolis, MN, May 29 - June 1 2018.
- **Keller AP**, Zornoza L, Ives SJ. The Mechanoreflex Response to Static and Dynamic Passive Limb Movement, American College of Sports Medicine's 63rd Annual Meeting, Boston, MA, May 2016
- Zornoza L, **Keller AP,** Ives SJ. Does Hyperoxia Alter the Mechanoreflex in Young Healthy Males and Females? American College of Sports Medicine's 63rd Annual Meeting, Boston, MA, May 2016

Regional Presentations *Slide presentation, ǂ Poster, †Award recipient

- ǂ **Keller AP,** Lefferts WL, Augustine JA, DeBlois JP, Wang Q, Heffernan KS. The Relationship between Body Mass Index and Aortic Stiffness in Females across the Lifespan. Neuroscience Research Day, Syracuse University, Syracuse NY, April 5 2019
- † *** Keller AP,** Lefferts WL, Augustine JA, DeBlois JP, Wang Q, Heffernan KS. The Relationship between Body Mass Index and Aortic Stiffness in Females across the Lifespan. Mid-Atlantic Regional Conference, American College of Sports Medicine, Harrisburg, PA, November 3 2018
- ǂ **Keller AP,** Lefferts WL, Augustine JA, DeBlois JP, Heffernan KS. Muscular Strength is Inversely Associated with Central Hemodynamic Load in Young Women, Neuroscience Research Day, Syracuse University, Syracuse NY, April 2018

- * **Keller AP,** Lefferts WL, Augustine JA, DeBlois JP, Heffernan KS. Muscular Strength is Inversely Associated with Central Hemodynamic Load in Young Women, Mid-Atlantic Regional Conference, American College of Sports Medicine, Harrisburg, PA, November 2017

Grants/Support

2018	Howard C. and Ethel G. Allen Educational Fund ($1732)

Awards

2018	Mid-Atlantic Regional American College of Sports Medicine Masters Student Research Award ($400)

Professional Organizations

2013 – Present	American College of Sports Medicine
2018 – Present	Mid-Atlantic Regional Chapter, American College of Sports Medicine
2016 – 2017	Executive Committee Member – Greater New York Regional Chapter, American College of Sports Medicine
2013 – 2017	Greater New York Regional Chapter, American College of Sports Medicine