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THE INFLUENCE OF AGING ON CARDIOVASCULAR MEASURES AFTER AN ACUTE BOUT OF RESISTANCE EXERCISE

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THE INFLUENCE OF AGING ON CARDIOVASCULAR MEASURES AFTER AN ACUTE BOUT OF RESISTANCE EXERCISE

A DISSERTATION APPROVED FOR THE
DEPARTMENT OF HEALTH AND EXERCISE SCIENCE

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I would like to dedicate this to my family, my professors, my friends, my Heavenly Father, and my Savior Jesus Christ. They have encouraged me along the way and helped me reach my full potential. I could not have done it without them.

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Abstract

As individuals age, substantial physiological changes occur. Most notably there is a decrease in muscle mass known as sarcopenia and an increase in arterial stiffness. In order to attenuate declines in muscle mass, resistance training effectively improves both muscle size and strength of older individuals. However, the effects of resistance training on the arterial system are less clear with studies noting increased, decreased, and no change in arterial stiffness after resistance training. **Purpose:** The purpose of this study was to determine how aging affected arterial stiffness and other cardiovascular measure responses to a whole body resistance training session. **Methods:** Thirty-six men were separated into three groups based on age (Young-aged, YG: 20-39 years; middle-aged, MG: 40-59 years; older-aged, OG: 60-75 years). A randomized controlled cross-over design was used. During one condition, participants rested for 30 minutes and in the other condition, participants performed whole-body resistance exercise consisting of leg press, bench press, knee flexion, lat pulldown and knee extension (3 sets of 10 reps at 65% one-repetition maximum for each exercise). Blood pressure, augmentation pressure, augmentation index, peripheral pulse wave velocity, central pulse wave velocity, heart function, and forearm blood flow were measured before and after each condition. Change scores from pre to post time points were used for analysis. Two-way repeated measures ANOVA was used to determine differences between conditions (exercise vs. control) and groups (YG vs. MG vs. OG). Statistical significance was set at $p \leq 0.05$. **Results:** No differences were found between age groups for blood pressure responses. When groups were combined, peripheral systolic blood pressure significantly increased after exercise when compared to the control condition (6 ± 7 vs. 1 ± 6 mmHg, p=0.003). Also, peripheral (-5 ± 6 vs. 2 ± 4 mmHg, p<0.001) and central diastolic blood pressures (-4 ± 6 vs. 2 ± 4 mmHg, p<0.001) significantly decreased when compared to the control condition. Augmentation index significantly increased after exercise when compared to the control condition for the YG (11 ± 8 vs. 0 ± 7%, p<0.001) but not for the MG (-1 ± 8 vs. -1 ± 5%, p=0.788) or OG (-3 ± 7 vs. 2 ± 4%, p=0.076). However, no significant changes were found for central pulse wave velocity. Heart function was also not altered substantially between age groups after exercise. **Conclusion:** It appears that some cardiovascular variables are affected more by aging than others after performing resistance exercise. Most notably, augmentation index is significantly elevated after resistance exercise in younger individuals but not in middle-aged and older-aged individuals when compared to a control condition. However, no significant increases were noted for central pulse wave velocity for any age group. Therefore, moderate resistance training does not appear to result in acute prolonged increases in arterial stiffness in middle-aged and older-aged adults.

Chapter I: Introduction

Aging influences every system in the body. From the brain and muscles, to the heart, each organ is affected in some degree by aging. In particular, the cardiovascular system and the neuromuscular system change with increasing age. In the cardiovascular system, age causes the arteries to become stiffer (82). This stiffening can have a negative effect on the cardiovascular system as a whole, and increases the risk of developing hypertension, left ventricular hypertrophy, and heart disease (48, 49). This increased arterial stiffening can result from decreased elastin, increased collagen, hypertrophied smooth muscle or even increased sympathetic tone (47).

With aging, not only is the cardiovascular system affected, but the neuromuscular system also experiences significant changes. One of the most dramatic changes that can occur in the neuromuscular system is the age-related loss of muscle mass, known as sarcopenia. This loss of muscle mass can begin as early as age 25 but muscle mass declines substantially after the age of 50 (52). In addition to the loss of muscle cross-sectional area, a significant decrease in type II muscle fiber size and number are reported, with type I fibers not having as great a decrease in size (51). Besides the loss of muscle fibers, spinal motor neurons numbers also decrease with age (1). The neuromuscular junction is affected such that a decrease in the number of synaptic vesicles and a greater distance from the axonal button to the motor end-plate are reported (1).

With these changes in the neuromuscular system, a significant decrease in power, strength, and functional ability become evident (58). However, many of these negative results can be counteracted, to a degree, through resistance exercise.

Resistance exercise can substantially increase muscular strength, power, and muscle size in older individuals (57). However, the muscle protein synthesis response to resistance training that causes muscle hypertrophy in older adults is less clear. Some studies find an attenuated muscle protein synthesis response in older adults (27, 33) while other studies reveal no differences in responses to resistance exercise in older adults when compared to younger adults (34, 92). A potential way to provoke a greater increase in muscle protein synthesis in older adults may be to increase the volume of exercise performed by these individuals (46).

Unfortunately, less is known about the consequences of resistance training on the cardiovascular system. Cross-sectional studies report a greater increase in arterial stiffness in resistance-trained men (14, 42, 61). In chronic resistance training studies equivocal findings are reported. Some studies in younger men report a significant increase in arterial stiffness and decrease in arterial compliance (41, 62). Other studies report no change, or even a decrease, in arterial stiffness (71, 75). In older adults, resistance training does not seem to alter arterial function, and one study even reported a significant decrease in arterial stiffness after resistance training (16, 71).

Because of the conflicting evidence from different chronic studies, it might be more important to understand the acute changes in the cardiovascular system following resistance exercise. Most studies have only investigated the cardiovascular responses of an acute bout of resistance training in younger men. Resistance training seems to significantly increase arterial stiffness or decrease arterial compliance by 30 minutes post-exercise, with levels returning to normal by 60 minutes (24). The high stress placed on the cardiovascular system in younger subjects who have more compliant arteries may result in acutely increased arterial stiffness, particularly in the proximal aorta. However, older subjects with increased arterial stiffness due to aging may not have a significant increase in arterial stiffness after resistance exercise.

To date, no studies have examined the acute responses to a resistance training bout over a wide span of ages. This is an important question and may potentially shed light on whether the change in arterial stiffness after an acute bout of training will be different due to differences in the stiffness of arteries from the aging process itself. Also, a variety of exercise protocols can be used, but a resistance exercise protocol that would promote muscle and is commonly used by older individuals should be investigated.

Purpose

The purpose of this study was to determine the influence of age on arterial stiffness, augmentation pressure, augmentation index, central and peripheral blood pressure, stroke volume, ejection fraction, cardiac output and forearm blood flow after an acute bout of moderate resistance exercise (65% 1-RM, 5 exercises, 3 sets of 10 repetitions).

Research Question

How does aging affect arterial stiffness, augmentation pressure, augmentation index, central and peripheral blood pressures, stroke volume, ejection fraction, cardiac output and forearm blood flow responses to an acute bout of moderate resistance exercise?

Subquestion

What is the influence of muscle mass on arterial stiffness and does the amount of muscle mass influence how stiff the arteries become after an acute bout of resistance exercise?

Hypothesis

It was hypothesized that between the ages of 18-39 years a significant increase in cardiovascular measures would be found post-exercise. It was also hypothesized that after the age of 40 years, an attenuated response in cardiovascular measures would be observed compared to individuals younger than 40 years.

Subquestion Hypothesis

It was hypothesized that greater amounts of muscle mass would result in greater increases in arterial stiffness due to an increased load on the arterial system after an acute bout of resistance exercise but that arterial stiffness measures would be greater at rest for individuals with smaller muscle mass.

Significance

No previous studies have examined the effects of age on the cardiovascular system after an acute bout of resistance exercise. The results of this study demonstrate how varying levels of arterial stiffness, due to the aging process, affect the arterial response to an acute bout of resistance exercise. Furthermore, this study determined the influence of muscle mass on arterial stiffness after an acute bout of resistance exercise.

Assumptions

1. It was assumed that participants were free of cardiovascular diseases and other neuromuscular diseases as reported by either the participant or their physician.

2. It was assumed that participants were fasted 3 hours prior to measurements, had not consumed caffeine, alcohol or anti-inflammatory medication 12 hours prior to measurements and had not exercised 24 hours prior to measurements.
3. It was assumed that participants accurately reported their levels of physical activity.

Delimitations

1. The findings in this study only apply to healthy men between the ages of 18-75 years old.
2. The sample was recruited from the surrounding areas of Norman and Oklahoma City, Oklahoma.

Limitations

1. This is an acute study, so conclusions about the effects of aging on chronic adaptations to resistance training cannot be made.

Operational Definitions

Arterial compliance: A measure of the elasticity of the arteries that is reflected from the relationship between pressure and volume changes in the artery. This is inversely related to arterial stiffness.

Augmented pressure: A measure of the difference in pulse wave pressure from the first systolic peak and second systolic peak. It represents the augmented pressure from the reflected pulse waveform.

Augmentation index: The ratio of the augmented pressure to pulse pressure expressed as a percentage which represents the index of pulse wave reflection**.**

Pulse wave velocity (PWV): The speed (meters per second) at which the pulse wave travels along the artery is related to the stiffness of the artery. The greater the PWV, the stiffer the artery is.

Stroke Volume: The volume of blood ejected during left ventricular contraction.

End-diastolic Volume: The volume of blood held in the left ventricle when the heart is relaxed.

Ejection Fraction: The ratio of stroke volume to end-diastolic volume that represents the fraction of blood ejected from the left ventricle during systole.

Cardiac Output: The volume of blood pumped by the heart during one minute.

Sarcopenia: The age-related loss of muscle mass as measured by the ratio of appendicular lean tissue mass (kg) to height (kg/m^2). Sarcopenia would be diagnosed if this ratio was greater than two standard deviations below the young adult mean.

Chapter II: Literature Review

Cardiovascular Changes with Aging

Over the course of a lifetime, many physiological changes naturally occur. All systems in the body gradually lose their efficiency to perform their functions, but two systems that are particularly affected by aging are the cardiovascular system and neuromuscular system. The cardiovascular system includes the heart, the blood vessels and the blood which carries needed nutrients and hormones throughout the body and also disposes of wastes. The heart is the pump of this system and pushes blood through the arteries and eventually back to the heart through the veins. The left and right ventricles contract and produce the needed pressure to overcome the pressure pushing back on the aortic and pulmonary semilunar valves. Oxygenated blood is then sent to the rest of the body, and deoxygenated blood is sent to the lungs. With aging both the heart and arteries decline in function. Specifically, a 40-50% difference in central arterial stiffness or compliance is found between ages 25 and 75 years, but not as much stiffening occurs in the peripheral arteries (63, 83).

Even healthy adults (20-91 years old) without known cardiovascular disease can have increased arterial stiffening (87). For example, in a group of Chinese individuals, arterial stiffening significantly increased from 2 months to 94 years (11). This increased stiffening is most likely due to a change in the arterial structural components. The structure of the arteries changes over time such that the arterial wall thickens and the elastic laminae thin and become damaged while connective tissue and collagen fibers increase (67). Furthermore, with aging, a lower ratio of elastic to collagen, smooth muscle cell hypertrophy or increased smooth muscle tone result (10). One way to measure this arterial stiffening is through pulse wave velocity (PWV). When the left ventricle contracts, a pressure waveform is sent along the arteries. The speed at which this pressure waveform travels is affected negatively by the stiffness of the arteries. Pulse wave velocity is measured by dividing the distance between two measurement sites by the time it takes for a pressure waveform to travel that distance (10). Arterial compliance is the inverse of arterial stiffening and represents the change in arterial diameter divided by change in pressure (68).

Not only are the arteries affected by aging but so is the heart. A thickening of the left ventricle with increasing age has been noted possibly due to higher arterial stiffness, thus increasing the pressure against which the heart must pump (56). Also, there is an increase in the filling time due to an increase in the duration of myocardial relaxation (74). In addition, pacemaker cells in the SA node, AV node, bundle of His and Purkinje fibers decrease over time (74). With respect to cardiac function, there is an increase in left ventricular end-diastolic pressure, an increase in early diastolic filling, an increase in myocardial stiffness and a decrease in baroreceptor sensitivity (74). Despite these changes, cardiac output is preserved at rest in older adults free of disease due to the Frank-Starling mechanism (74).

Neuromuscular Changes with Aging

Even as the cardiovascular system is changing with age, the neuromuscular system is also changing. One of the most notable effects of aging on the neuromuscular system is the age-related loss of muscle mass, also known as sarcopenia. Sarcopenia is defined by using the ratio of appendicular lean tissue mass (kg) to height (kg/m^2) (13). If this ratio is greater than two standard deviations below the mean of younger adults, then sarcopenia would be indicated (13). This loss of muscle mass can begin as early as 25 years of age, but a greater decline in muscle mass is found after the age of 50 (52). The prevalence of sarcopenia can increase from 5% of people aged 65 to as much as 50% of people aged 85 and over (64). Frontera et al. (31) followed participants from ages 65 to 77 and found an average of 14.7% loss of total thigh muscle cross-sectional area (CSA), a 16.1 % loss of quadriceps femoris CSA and a 14.9% decrease in leg flexor muscle CSA. In a cross-sectional study by Lexell et al. (52), the researchers estimated that after age 50 there is a 1% loss in muscle CSA per year.

Interestingly, not all muscles seem to be affected the same way by aging. For example, one study found that a greater decline in muscle mass in the lower extremities when compared to the upper extremities (38). In addition, one study of Japanese women noted a site-specific decline in anterior upper and mid-thigh muscle thickness but not in the posterior thigh muscle thickness (7). This finding is supported by other studies showing similar declines in the anterior leg muscles but not posterior leg muscles (4, 32). Thus, differences in the loss of muscle mass may be happening at different rates in different muscle groups.

When examining the effects of aging on muscle fibers, both type I and type II fibers are altered. Specifically, type II fibers exhibit decreases in muscle fiber CSA and in total number (51). However, type I fibers tend to not to change in muscle fiber CSA and type II fibers become type I fibers through axonal sprouting (1). This results in a grouping of fibers types instead of the usual mosaic pattern of muscle fiber types. Despite changes in muscle fiber CSA and number, the intrinsic power of muscle fibers does not seem to decrease with age (76, 86).

Part of the resulting loss in skeletal muscle fiber and size is due to a loss of spinal motor neurons which can be due to apoptosis, reduced IGF-1signaling, increased cytokine levels or cell oxidative stress (1). A 50% reduction in spinal motor neurons was found when comparing 20-40 year old subjects to subjects over the age of 60 (85).

The overall result of a decrease in muscle CSA, muscle fibers, and decreased nervous system capability is the age-related loss of strength, which has been termed dynapenia (58). It is well established that muscle strength declines with aging (25). Loss of strength ranges from 20% to 40% by the seventh and eighth decades of life and can be greater than 50% in the ninth decade of life (25). Despite the well-established fact that strength declines with age, the relationship of decreases in strength to losses in muscle mass remains a topic of interest. For example, Delmonico et al. (23) designed an interesting study that looked at the relationship between declines in muscle strength and declines in muscle mass in 1678 men and women over a five-year period. The average age of participants at the beginning of five years was 73 years. Thigh muscle CSA was measured using CT scans at the midfemur and strength was assessed by using the average maximum isokinetic muscle torque of participants at 60 degrees/second. The researchers found that knee extensor torque in men decreased by 16% but they only had a decrease of 5% in total thigh muscle CSA and that in women knee extensor torque decreased by 14% and total thigh muscle CSA decreased by 3%. In addition, researchers also reported a significant increase in intramuscular fat in both men and women over the five-year period. Overall, strength declines with age, but this may not be solely related to declines in muscle mass, as the rate at which these two measures decrease is not the same.

Besides muscle influencing some of the strength-related declines with aging, decreased muscle mass found with aging is reported to be associated with increased arterial stiffness. Ochi et al. (69) examined the relationship between arterial stiffness (brachial-ankle) and thigh muscle CSA (CTscan) in 468 men and women. A significant inverse relationship was found with arterial stiffness and muscle CSA. Another study followed 2,405 participants over 6 years to determine the rate of changes between arterial stiffening and loss in muscle mass. At baseline levels, the researchers found an independent negative association between arterial stiffness and lean arm mass, lean leg mass, and skeletal muscle density in men while in women arterial stiffness was only negatively associated with sarcopenic index and leg lean mass (2). Using multivariate regression, the authors also determined that the increase in arterial stiffness was related to increases in the sarcopenic index independent of age. Other evidence supporting this finding includes a study by Loenneke et al. (54), which reported that thigh muscle CSA as measured by peripheral quantitative computed tomography was inversely correlated with increases in augmented pressure and augmentation index, two indirect markers of arterial stiffness. From these studies, muscle mass seems to play a role in arterial stiffness but a causal relationship has yet to be established.

Resistance Training Effects on Strength, Functional Ability, and Muscle Mass

In order to combat sarcopenia, numerous interventions including nutritional supplements, resistance training, or pharmacological interventions have been tried. One effective way to increase muscle mass and muscular strength is through resistance training. Despite the effects of age, older adults can increase muscular strength, power, and functional ability through resistance exercise (57). Important components of resistance training that can be altered include the intensity, the frequency and the volume of training. Different combinations of these components can produce varying results. A meta-analysis by Steib et al. (80) found that training between 60-80% 1-RM produced the greatest strength gains in older adults but the adaptations in functional ability were not different between high, moderate, or low-intensity resistance training. Intriguingly, low-intensity resistance training (20-30% 1-RM) when combined with blood flow restriction produces significant increases in muscle mass and strength and can thus be employed in older populations who may not be able to perform high-intensity training (55).

One crucial outcome to examine related to whether resistance training is truly combating sarcopenia is to examine the muscle hypertrophy response to resistance training. In order to increase muscle size, muscle protein synthesis must be greater than muscle protein degradation. At basal levels, the muscle protein synthesis and muscle protein degradation do not seem to differ between older individuals and their younger counterparts (88). However, the results to a bout of resistance exercise do seem to vary. Some studies find an attenuated muscle protein synthesis response in older adults (27, 33), while other studies reveal no differences in responses to resistance exercise in older adults compared to younger adults (34, 92). However, when compared to younger adults, older adults may need a larger volume stimulus to increase muscle protein synthesis. Kumar et al. (46) determined that doubling the volume of resistance exercise from 3 sets of 14 repetitions to 6 sets of 14 repetitions (40% 1-RM) or from 3 sets of 8 repetitions to 6 sets of 8 repetitions (75% 1-RM) significantly increased muscle protein synthesis responses in older men to levels that were similar to those of younger men.

Older adults seem to have some anabolic resistance to resistance training for muscle hypertrophy but a greater volume is potentially needed to overcome this change with aging.

Resistance Training Effects on the Cardiovascular System

Indeed, resistance training is a key component to counteract the effects of sarcopenia. While resistance training may positively affect the neuromuscular system, its effects on the cardiovascular system need more investigation. To date, cross-sectional, chronic, and acute studies have been used to examine the effects of the resistance training on the cardiovascular system. However, equivocal findings currently make it difficult to decipher the exact consequences of resistance training for the cardiovascular system. The next few sections will discuss the findings of cross-sectional, chronic and acute resistance exercise on the cardiovascular system, with an emphasis on different age responses.

Cross-sectional Studies

Some cross-sectional studies examining the relationship between resistance training and arterial health have pointed to the idea that resistance trained men have decreased arterial compliance and increased arterial stiffness. For example, one study investigated cardiovascular differences in 19 young men (~26 years old) who had resistance trained for a minimum of three times a week for at least 12 months (no aerobic training) and compared them to a sedentary group who had not participated in an exercise program during the past 12 months (14). The researchers found that resistance trained men had significantly lower aortic compliance, higher β-stiffness index and carotid pulse pressure, higher peripheral PWV (femoral-dorsalis pedis arteries) and a similar central PWV (carotid-femoral arteries) compared to the sedentary group. When comparing left ventricular mass, the resistance-trained group had a larger mean mass, but this was no longer significant when normalized for body size.

The finding that central PWV was not different compared to the sedentary group is surprising, as greater β-stiffness index and carotid pulse pressure, a measure of stiffness in the aortic arch, were found in the resistance-trained group. The authors suggest that central PWV measurement does not include the proximal part of the aorta and this is why central arterial stiffness may not have been different between groups (14). The results of this study indicated that resistance-trained men have decreased arterial function but no difference in left ventricular size or function when normalized for body weight. However, the exact amount of time that participants had been resistance training or the type of resistance training they performed was not reported so precise conclusions on the effects of resistance training cannot be made from this study.

Interestingly, a similar finding was reported by Miyachi et al. (61) who examined both young and middle-aged men who were either sedentary (~27 vs. ~51 years old) or resistance-trained (~29 vs. ~51 years old). Sedentary men had not participated in a regular exercise program in the previous two years while resistance-trained men (no regular aerobic exercise) had trained for more than two years. The average training periods of younger and middle-aged men were five and 21 years respectively. The authors found that the age-related decline in arterial compliance was 30% greater in the middle-aged resistance-trained men compared to their sedentary counterparts. On the other hand, no difference in arterial compliance was reported in younger sedentary and resistance-trained men. Arterial compliance was also inversely correlated with the number of years of resistance training. In addition, the authors also noted that left ventricular hypertrophy mass and index were greater in resistance-trained men when compared to sedentary men for their respective age group.

Another cross-sectional study sought to determine if resistance training impaired arterial endothelial function (42). A cold pressor test was performed in resistance-trained men ranging from the ages of 28-49 years. Resistance-trained men had performed vigorous resistance training for greater than 10 years with no concurrent aerobic training performed. Resistance trained men had significantly higher brachial and carotid blood pressures and carotid arterial compliance was significantly lower than the control group. Furthermore, β-stiffness index was significantly higher in the resistance-trained men but after adjusting for mean arterial pressure, the differences were no longer statistically significant. The change in carotid arterial diameter during the cold pressor test did not differ significantly between groups, indicating that endothelial function was not impaired relative to sympathetic activity in resistance-trained men. Also, carotid artery diameter and intima-media thickness were not different between groups. Therefore, the lower arterial compliance in resistance-trained men could not be explained by differences in endothelial function or carotid artery diameter. Hence, any differences between the groups may more likely be due to changes in the elastic and collagen components.

Chronic Studies

Cross-sectional data limit our conclusions due to numerous uncontrolled factors. However, chronic resistance training enables researchers to investigate how the cardiovascular system will respond to multiple training sessions while controlling for many other factors. When investigating how resistance training chronically affects the cardiovascular system, varying results are reported. Differences in the studies investigating this include the type of measurement devices (ultrasonography vs. applanation tonometry), resistance training protocols, age, gender and duration of training. The number of weeks trained ranges from 4 weeks to 4 months. Two studies that trained young men for 4 months with either moderate (50% 1-RM) or high intensity (80% 1-RM) whole body resistance training indicated that arterial stiffness was significantly elevated or that arterial compliance was significantly decreased (41, 62). One study by Cortez-copper et al. (22) observed that, after 11 weeks of resistance training using sets with low reps and high weight, central arterial stiffness significantly increased in young women but peripheral arterial stiffness did not. Unfortunately, it cannot be concluded from this study that resistance training actually caused this increase because central arterial stiffness was significantly elevated in the control group to levels that were higher than in the resistance training group after 11 weeks. Another study reported that central PWV increased from 11.0 m/s to 12.7 m/s (14.5%) and that peripheral PWV increased from 11.5 m/s to 12.5 m/s (8.7%) in pre-hypertensive women (~47 years) after 4 weeks of resistance training (20). These studies suggest that arterial stiffness may increase in younger men and women and pre-hypertensive women who perform resistance training.

On other hand, multiple studies suggest that resistance training may not have a negative impact on the cardiovascular system. Rakobowchuk et al. (75) had young men perform whole body resistance training and determined its effects on arterial compliance. After 12 weeks of performing high-intensity resistance training (80% 1-

RM), no significant changes were found in arterial compliance. Casey et al. (15) came to similar conclusions when they found no significant changes in aortic pressure wave reflections or central and peripheral PWV in young men and women who performed 2 sets of 8-12 repetitions to failure for 12 weeks. Even when resistance training is performed by post-menopausal women for 18 weeks, no significant changes in arterial pressure wave reflections or augmentation index are found (16).

Some studies even demonstrate a positive effect on the cardiovascular system from resistance training when performed at lighter intensities. Okamoto et al. (71) reported that premenopausal women who exercised at home using body weight and hand-held weights for 10 weeks had decreases in arterial stiffness. Unfortunately, no control group was included in this study. However, Okamoto et al. (70) had young men and women perform moderate-intensity resistance exercise (50% 1-RM) and a reduction in peripheral PWV was reported when compared to a control group. The many differences in exercise protocols, duration and age groups make it difficult to decipher exactly how resistance training affects the cardiovascular system, especially with respect to age.

Acute Studies

One way to potentially examine some of differences in the response of the cardiovascular system to resistance training especially with regards to age is to examine the acute response. Surprisingly, however, almost all of the acute studies have used younger populations. When examining arterial compliance following a resistance training bout of nine exercises, DeVan et al. (24) reported that young men and women (~27 years) had significantly decreased central arterial compliance at 30 minutes post exercise but central arterial compliance returned to baseline levels by 60 minutes. Yoon et al. (93) also reported that after performing eight resistance exercises at 60% 1-RM, central arterial stiffness in young men increased at 20 minutes but not 40 minutes. However, another study found that central arterial stiffness remained elevated at 60 minutes in young men (19). Differences in the results of these two studies may come from the differences in exercise protocols used. DeVan et al. (24) had participants perform 1 warm up set of 8-12 repetitions at 50% 1-RM and then a second set at 75% 1-RM to failure, Yoon et al. (93) had subjects exercise at 60% 1-RM for 2 sets of 15 repetitions, and Collier et al. (19) had participants exercise for 3 sets at 100% of their 10-RM.

Another study of young men (~25 years) also reported that central arterial stiffness significantly increased from 4.8 to 5.8 m/s but peripheral PWV did not significantly change (8.7 to 9.0 m/s) in young men who performed 8 resistance exercises (35). Even when participants only perform upper body exercises, it has been noted that arterial stiffness may increase after an acute bout of exercise. Fahs et al. (29) noted that young men who performed 4 sets of 5 reps at 80% 1-RM of bench press and 4 sets of 10 reps at 70% 1-RM for biceps curl exhibited increases in central arterial stiffness and an increase in augmentation index 15 minutes post-exercise.

Only one study, to the author's knowledge, investigated cardiovascular response differences between young and middle-aged men after resistance exercise. Unfortunately, only blood pressure responses were recorded before and after resistance exercise. At baseline, middle-aged men (~48 years) had significantly lower arterial compliance (0.11 vs. 0.17 mm^2/mmHg) and significantly higher carotid β-stiffness index (7.3 vs. 3.95 a.u.) and brachial-ankle PWV (1,291 vs. 1092 cm/s) compared to the young men. The exercise protocol had subjects perform 3 sets (40, 60, 80% 1-RM) of 10 repetitions. After performing this exercise protocol, middle-aged men had an attenuated response in systolic blood pressure (SBP) and diastolic blood pressure (DBP) compared to young men. Thus, it is quite possible that attenuation in arterial stiffness responses would be observed in middle-aged men compared to younger-aged men.

With regards to the acute experiments on how aging influences the cardiovascular response to resistance exercise, a paucity of research exists. Therefore, a greater understanding of how age affects the cardiovascular and hemodynamic response to an acute bout of resistance training is needed and such studies would lead to advances in understanding how resistance exercise affects the cardiovascular system.

Chapter III: Methodology

Participants

Participants were recruited from men ranging in age from 18-75 years. They were recruited from the Norman and Oklahoma City, Oklahoma areas. Participants who were 45 years or older were required to have their physician approve their involvement prior to beginning the study.

Inclusion Criteria

1. Men ranging between the ages of 18-75 years.
2. Recreationally active men.
3. No known orthopedic disorders that would prevent participation in the exercise session.
4. Body mass under the DXA weight limit (300 1bs).
5. Free from pulmonary, cardiovascular or metabolic diseases (asthma, diabetes, heart, uncontrolled hypertension or COPD).
6. Not hypertensive (SBP > 140 and/or DBP > 90) – this was either naturally or under control with medication.

Exclusion Criteria

1. Men outside the age range of 18-75 years.
2. Any pulmonary, cardiovascular or metabolic diseases (asthma, diabetes, heart or COPD)
3. BMI ≥ 30 kg/m^2.

4. Highly resistance trained (in a resistance training program lifting ≥ 3 times per week within the previous 6 months or competitively lifted during the previous 2 years).
5. Highly endurance trained (perform vigorous endurance exercise ≥ 5 times per week within the previous 6 months or competitively raced during the previous 2 years).
6. Body mass over the DXA weight limit (300 lbs).
7. Taking anabolic steroids.
8. Smokers.

Experimental Design

A randomized controlled cross-over design was used in this experiment. Participants were males and separated into three different groups according to their age. One group included participants ranging from the ages of 20-39 years, the second group 40-59 years and the third group 60-75 years. Participants 45 years and older needed their personal physician to fill out a medical questionnaire and recommend them to participate.

During the first visit, participants were screened and filled out a physical activity readiness questionnaire (PAR-Q), health status questionnaire, protected health information (PHI) authorization release form, and consent form. Resting blood pressure and ankle brachial index were measured to screen for hypertension and peripheral vascular disease. After those measurements, standing height and weight were measured. Participants were then familiarized with the one-repetition maximum (1-RM) procedures for the leg press, chest press, knee flexion, lat pull-down, and knee extension by performing several repetitions at a light load and then slightly increasing the load so that participants felt how the weight would change during the 1-RM procedure.

At the second visit, muscle thickness (biceps, triceps, quadriceps, and hamstrings) was measured and a whole body DEXA scan was performed. Subjects were encouraged to come to the visit well-hydrated and hydration status was checked using a spectrometer (urine specific gravity values between 1.004-1.029). Following these tests, 1-RM tests for the leg press, chest press, knee flexion, lat pull-down, and knee extension were performed.

Visit three and four were randomized such that one visit was a control visit while the other visit was the exercise session. At least 3 days separated the third and fourth visits (35). At the beginning of the third visit, muscle thickness was measured again.

During the control condition (CON) participants lay supine on a medical table for 8-10 minutes. Subjects were at least three hours postprandial, had not exercised for 24 hours, and had not consumed caffeine/alcohol at least 12 hours prior to testing. After resting for 8-10 minutes, cardiovascular measurements were taken, which included resting blood pressure, radial pulse wave analysis (augmentation pressure, augmentation index, and central blood pressure), radial-carotid (peripheral) and femoral-carotid (central) PWV, heart rate, stroke volume, cardiac output, ejection fraction and resting forearm blood flow. After these measurements, participants sat in a chair for ~ 20 minutes. Following the control waiting period of ~20 minutes, participants lay supine on a medical table for ~10 minutes and then all the previous cardiovascular measurements were taken again.

For the exercise condition (EX), participants lay supine on a medical table for 8-10 minutes. Cardiovascular measurements were then taken, which included resting blood pressure, radial pulse wave analysis (augmentation pressure, augmentation index, and central blood pressure), peripheral and central PWV, heart rate, stroke volume, cardiac output, ejection fraction and resting forearm blood flow. After these measurements, participants performed resistance exercise consisting of five exercises: leg press, chest press, knee flexion, lat pull-down, and knee extension in that order. ACSM recommendations were used for the exercise protocol such that three sets of 10 repetitions were performed at ~65% of the participant's 1-RM with 2-3 minutes of rest between sets. After all the exercises were completed, participants lay supine on a medical table ~5 minutes and then all the previous cardiovascular measurements were taken.

Standing Height and Weight

Participants removed shoes and any hat. A stadiometer (Stadi-0-Meter®, Novel Products, Inc., Rockton, Illinois, USA) measured height to the nearest cm. Participants placed feet together with heels, buttocks and upper back against the wall with back straight and in the middle of the stadiometer. Participants looked straight ahead with chin at a 90 degree angle. Participants took a deep breath and exhaled. Weight was measured on a digital scale (TANITA Digital Scale, model BWB-800A, Japan). Participants removed shoes and emptied pockets of any items. The digital scale was turned on and set to kg and participants stood on the scale with both feet, and weight measured to the nearest 0.1 kg.

Cardiovascular Parameters

Before testing of cardiovascular parameters subjects did not consume any caffeine/alcohol in the previous 12 hours or exercise in the previous 24 hours and were at least 3 hours postprandial (35). Subjects lay supine for a period of 8-10 minutes before testing. All parameters for each participant were taken at similar times of the day.

Brachial Blood Pressure (BP)

An automatic blood pressure cuff (Omron Healthcare Inc, Vernon Hills, IL) was used to measure blood pressure. A blood pressure cuff was placed around the right upper arm. Cuff size was determined by measuring arm circumference at the midpoint of the arm (midpoint between olecranon and acromion process). An adult cuff was used for arm circumferences ranging from 22-32 cm and a large adult cuff was used for circumferences ranging from 32-42 cm. Two blood pressure measurements, separated by 1 minute, were taken at rest and after exercise. If the two systolic blood pressures differed by more than 5 mmHg, then a third blood pressure measurement was taken. The average of the two most similar blood pressure measurements was used for analysis.

Arterial Measurements

Applanation tonometry (SphygmoCor, AtCor Medical, Sydney, Australia) and a high-fidelity strain-gauge transducer (Miller Instruments, Houston, TX, USA) were used to measure the radial arterial pressure pulse waveforms. A generalized validated transfer function (SphygmoCor, AtCor Medical, Sydney, Australia) derived central blood pressures from radial blood pressure waveforms. Applanation tonometry and three ECG electrodes measured PWV. A high-fidelity strain-gauge transducer was placed on the right common carotid artery and right femoral artery and the pressure waveform was measured at each location. The distance (measured with a tape measurer) from the right common carotid artery to the suprasternal notch was subtracted from the distance from the suprasternal notch to the right femoral artery and used as the distance to calculate the PWV. The time delay from the R-wave of the ECG and the foot of the pressure waveform of the femoral arterial segment was subtracted from the time delay from the R-wave of the ECG and the foot of the pressure waveform of the carotid arterial segment to determine the transit time. The same procedure was also done with the radial and carotid arteries to determine the peripheral PWV. Pulse wave velocity was calculated as the distance between arterial segments divided by the transit time.

Heart rate was determined from the time between waveforms. Augmentation pressure, a measure of how much the initial aortic wave is augmented by the reflected aortic pressure wave from the periphery, was determined using specialized software (SphygmoCor; AtCor Medical, Sydney, Australia). The augmentation index was calculated by dividing the augmentation pressure by the aortic pulse pressure and was expressed as a percentage. Both measures were corrected for heart rate and expressed relative to a heart rate of 75 bpm.

Forearm Blood Flow

Forearm blood flow was measured using venous occlusion strain-gauge plethysmography (EC-6; Hokanson Bellevue, WA, USA). Participants rested supine for 10 minutes. The forearm was elevated 10-15 cm above heart level using a foam pad. A venous occlusion cuff was placed on the wrist (SC10) and an arterial occlusion cuff on upper arm (SC12). The largest circumference of the forearm was measured and then a mercury-filled strain gauge that was 2 cm less than the largest circumference was placed around the forearm. The venous occlusion cuff was inflated to 200 mmHg for 1 minute, after which the E20 rapid cuff inflator (set to 50 mmHg) was inflated for 7 seconds and deflated for 8 seconds. Forearm blood flow was then normalized to mean arterial pressure (FBF/MAP*1000) (flow/mmHg) for forearm vascular conductance.

Heart Measurements

Heart measurements were taken using two-dimensional M-mode echocardiography ultrasound unit with a 3.5 MHz probe (Fukuda Denshi UF-750XT, Tokyo, Japan). The subject lay supine on a medical table and rested for 10 minutes prior to baseline testing. After 10 minutes, the heart was located using the parasternal long-axis view. Three heart beats were measured and the average value from the three beats was reported. At the end of the systole and diastole, left ventricular internal diameter was measured. The Teicholz method was used to determine end systolic and end diastolic volumes [End-diastolic volume (ml) = (7 x (end diastolic diameter)^3)/(2.4+end-diastolic diameter) x and end systolic volume (ml)=(7 x (end systolic diameter)^3)/(2.4 + end-systolic diameter) (84)]. Stroke volume (SV) was calculated as EDV-ESV. SV Index (SV_Index) was calculated by dividing SV by body surface area (BSA). Cardiac output was calculated by multiplying SV x heart rate. Cardiac output index (Q_Index) was calculated by dividing cardiac output by BSA. Body surface area (cm^2) was estimated using the equation from Dubois and Dubois (28) [BSA=71.84 x Height (cm)^0.725 x Weight (kg)^0.425] and was then converted to m^2 for analysis. Ejection fraction was calculated by dividing SV by end-diastolic volume x 100.

Ankle-Brachial Index

Participants lay supine on a medical bed for 10 minutes prior to testing. After 10 minutes a blood pressure cuff was placed around the right arm. A Doppler probe (Hokanson, Inc) was placed on the brachial artery, the blood pressure cuff was slowly inflated and the highest pressure at which blood flow was present was recorded. A blood pressure cuff was then placed on the lower leg around the right ankle. A Doppler probe was placed at the posterior tibial artery and the highest pressure at which blood flow was present was recorded. Ankle pressure was then divided by the brachial pressure. If ankle-brachial index was less than 0.9, the participants were excluded from the study.

Muscle Thickness

Muscle thickness was measured using B-mode ultrasound imaging with a 5.0 MHz probe (Fukuda Denshi UF-750XT, Tokyo, Japan). Muscle thickness was measured at the triceps, biceps, quadriceps and hamstring muscle groups. The triceps was located on the posterior side of the upper arm at 60% distal between the acromion process and lateral epicondyle while the biceps was located on the anterior side of the upper arm at 60% distal between the acromion process and lateral epicondyle (3).

Quadriceps and hamstring muscles were located on the anterior and posterior surface of the upper leg at the midpoint between the greater trochanter and lateral condyle of the femur (3). Two measurements were taken at each site. There was no significant difference using paired sample t-tests between the two measurements for each muscle site ($p>0.05$) and the two measurements were significantly correlated with each other for each muscle site ($r>0.994$), so the average of the two measurements was used for analysis. Muscle thickness was determined as the distance between the adipose tissue-muscle interface and muscle-bone interface from the ultrasound image. The same testing sites were used for both days by marking the site with a permanent marker. Muscle thickness (MTH) ratios were calculated in the upper leg by dividing the quadriceps by the hamstrings MTH (Q:H MTH ratio) and in the upper arm by dividing the biceps by the triceps MTH (B:T MTH ratio).

Strength

One-repetition maximum standard procedures were used to assess participants' muscular strength. Each participant was familiarized with the 1-RM protocol and weight machines (Cybex® isotonic weight machines) on the first visit. Participants performed 1-RM tests following standard 1-RM procedures (12). For example, an estimated 50% of participant's 1-RM was performed between 8-10 times. Participants rested for 1 minute and then performed 3-5 repetitions at 60-80% of their 1-RM. After a 1 minute rest, participants performed one repetition and continued this pattern until the maximum amount of weight was lifted one time. Between maximal lifts, participants rested between 2-3 minutes. Strength testing included leg press, chest press, knee flexion, lat pulldown, knee flexion in that order.

Muscle Quality Index

Muscle quality index was determined using several criteria. Using MTH, knee flexion strength was divided by hamstrings MTH, knee extension strength was divided by quadriceps MTH, and total leg strength (leg press plus knee extension plus knee flexion) was divided by total leg MTH (hamstring MTH plus quadriceps MTH). Also, total leg strength (leg press plus knee extension plus knee flexion) was divided by leg lean tissue.

Body Composition

Dual Energy X-ray Absorptiometry (DXA, GE Medical Systems, Lunar Prodigy, encore 2010 software version 13.31.016) assessed total bone free lean body mass using a total body scan in all participants during the second visit. The DXA machine was calibrated on each testing day prior to scanning participants, and the scanning procedures were standardized for all participants. Participants dressed in light clothing with no attenuating materials (e.g., metal). Participants were placed in a supine position and arms were placed close to the sides of the body within the 60 cm scanning area on the DXA table. Velcro straps were placed around the knees and ankles to hold the legs together during the scans. Hydration status was determined using a refractometer. Subjects were considered hydrated if urine specific gravity was between 1.004 to 1.029 (9). The lab %CV for total bone free lean tissue body mass was 1.27%.

Statistical Analysis

Differences between age groups and conditions were measured using a two-way repeated measures ANOVA [2 conditions (EX vs. CON) x 3 groups (YG vs. MG vs. OG)]. The changes scores from pre to post for each condition were used in the analysis.

If a significant interaction term was found, simple effects analysis using one-way ANOVA and paired sample t-tests was used. If a significant condition main effect was found, paired sample t-tests were used on the marginal means. If a significant group main effect was found, independent t-tests using a Bonferroni correction were performed on the marginal means. A one-way ANOVA determined differences between groups at baseline for all variables. The average values for muscle thickness (visit 2 and 3) and resting cardiovascular measures (visit 3 and 4) were used to analyze baseline group differences. If the F-ratio was significant, follow-up testing was performed using Tukey's post hoc test if Levene's test of homogeneity of variance was not significant. A Dunnett C test was used for follow-up testing if Levene's test of homogeneity of variance was violated. Pearson r-correlations and partial correlations were used to determine if there was any association between changes in arterial stiffness and muscle mass and changes in arterial stiffness and exercise volume while controlling for age. Reliability of muscle thickness and cardiovascular parameters was determined by calculating intraclass correlation coefficient ($ICC_{3,1}$), standard error of the mean (SEM) and minimal difference (MD) (90). Statistical significance was set at $p \leq 0.05$. All data are represented as mean ± standard deviation.

Chapter IV: Results and Discussion

Results

Participant Characteristics

A total of 43 participants were enrolled at the beginning of the study; however, four of those participants did not meet final inclusion criteria due to a BMI ≥ 30 kg/m^2 or SBP ≥ 140 mmHg. One participant never received medical clearance from his doctor and another one could not finish the exercise session due to some nausea and light headedness so they were excluded from the study. Participants were divided into a young-aged group (YG, n=12, 26.5 ± 3.3 yrs), middle-aged group (MG, n=14, 49.4 ± 5.2 yrs) and older-aged group (OG, n=10, 67.4 ± 6.3 yrs). No significant differences were found between age groups for height (p=0.63), body mass (p=0.15) or body mass index (BMI, p=0.39) (Table 1).

Participants self-reported that the average number of days that they performed aerobic training was 3 days per week (n=18; the other 18 participants did not report any significant aerobic training but considered themselves recreationally active) and that they performed structured resistance training 2 days per week (n=17; the other 19 participants did not report any significant resistance training).

Three participants reported taking cholesterol medication (n=3, Lipitor and Gemfibrozil), two in the OG and one in the MG. Two participants reported taking hypertensive medication (Lisinopril and HCT2), one in the OG and the other in the MG. One subject in the YG was taking Adderall and one subject in the YG was taking hypothyroid medication.

Table 1. Participant Characteristics

	YG (n=12)	MG (n=14)	OG (n=10)
Age (yrs)	26.5 ± 3.3	49.4 ± 5.2	67.4 ± 6.3
Height (m)	1.76 ± 0.06	1.78 ± 0.07	1.78 ± 0.07
Weight (kg)	74.6 ± 7.5	81.7 ± 9.7	77.6 ± 10.0
BMI (kg/m^2)	24.3 ± 1.8	25.7 ± 2.7	24.8 ± 3.4
Right Side ABI	1.1 ± 0.1*	1.2 ± 0.1	1.2 ± 0.1
Left Side ABI	1.1 ± 0.1	1.2 ± 0.1	1.2 ± 0.1

Data presented as mean ± SD; BMI=Body mass index; ABI=Ankle Brachial Index; *$p \leq 0.05$ from MG and OG

Body Composition

The age groups were similar in total body fat percentage (p=0.77), total fat (p=0.48), total lean tissue (p=0.18), total fat free tissue (p=0.19) and sarcopenia index (p=0.08) (Table 2). A significant one-way ANOVA (p=0.049) was found for leg lean tissue (kg); however, follow-up analysis revealed no significant difference between age groups (YG vs. OG, p=0.84; YG vs MG, p=0.16; MG vs OG, p=0.57). No significant differences were found between groups for arm lean tissue (p=0.19) or trunk lean tissue (p=0.32). The number of individuals with a sarcopenia index below 7.26 was two in the YG, one in the MG and three in the OG. All participants were adequately hydrated prior to body composition measurements, with urine specific gravity measuring between 1.004-1.029.

Table 2. Body Composition

	YG (n=12)	MG (n=14)	OG (n=10)
Body Fat%	21.7 ± 6.1	23.6 ± 8.6	23.6 ± 7.7
Total Fat Tissue (kg)	15.6 ± 5.0	19.0 ± 8.2	18.1 ± 7.8
Total Lean Tissue (kg)	55.9 ± 5.9	59.6 ± 6.4	56.2 ± 3.7
Total Fat Free Tissue (kg)	59.0 ± 6.1	62.9 ± 6.7	59.6 ± 3.7
Arm Lean Tissue (kg)	6.7 ± 1.0	7.1 ± 0.9	6.5 ± 0.6
Leg Lean Tissue (kg)	18.1 ± 1.8	19.6 ± 2.3	17.6 ± 1.8
Trunk Lean Tissue (kg)	27.0 ± 3.2	28.7 ± 3.2	28.1 ± 1.6
Sarcopenia Index (kg/m^2)	8.0 ± 0.7	8.4 ± 0.7	7.7 ± 0.9

Data presented as mean ± SD

Muscle Thickness

Table 3 and Figure 1 describe differences in MTH between groups. The average of the two muscle thickness measurements from visits two and three was used for analysis. Muscle thickness was significantly different between groups for the quadriceps (p=0.006), biceps (p=0.048), triceps (p=0.02), H:Q MTH ratio (p=0.03) and B:T MTH ratio (p=0.004). However, hamstring MTH was not significantly different between groups (p<0.99). Further post-hoc analysis revealed that quadriceps MTH was significantly greater in the YG compared to the OG (p=0.004) but no differences were found between the YG and MG (p=0.30) or MG vs. OG (p=0.09). Biceps MTH was significantly lower in the YG compared to the MG (p=0.047) but not the OG (p=0.17), nor between the MG and OG (p=0.90). Triceps MTH was significantly lower in the OG compared to the MG (p=0.02) but not the YG (p=0.09), nor between the YG and MG (p=0.84). The Q:H MTH ratio was significantly lower in the OG compared to the YG (p=0.03) but not the MG (p=0.24), nor between the YG and MG (p=0.46). The B:T

MTH ratio was significantly lower in the YG (*p*=0.004) and MG (*p*=0.02) compared to the OG but not between the YG and MG (*p*=0.70).

The Intraclass Correlation Coefficient, ($ICC_{3,1}$) for MTH measurements was 0.95 for quadriceps MTH, 0.91 for hamstrings MTH, 0.94 for biceps MTH and 0.95 for triceps MTH. The standard error of the measurement (SEM) was 0.15 cm for quadriceps MTH, 0.17 cm for hamstrings MTH, 0.11 cm for biceps MTH and 0.15 cm for triceps MTH. The minimum difference (MD) needed to see real changes was 0.42 cm for quadriceps MTH, 0.48 cm for hamstrings MTH, 0.30 cm for biceps MTH and 0.40 cm for triceps MTH.

Table 3. Muscle Thickness

	YG (n=12)	MG (n=14)	OG (n=10)
Quadriceps MTH (cm)	5.48 ± 0.56‡	5.13 ± 0.56	4.59 ± 0.69*
Hamstrings MTH (cm)	6.00 ± 0.68	5.97 ± 0.44	5.99 ± 0.70
Biceps MTH (cm)	3.48 ± 0.30†	3.88 ± 0.50*	3.80 ± 0.34
Triceps MTH (cm)	3.87 ± 0.52	4.00 ± 0.52‡	3.31 ± 0.78†
Q:H MTH Ratio	0.93 ± 0.19‡	0.86 ± 0.08	0.77 ± 0.12*
B:T MTH Ratio	0.91 ± 0.10‡	0.98 ± 0.12‡	1.22 ± 0.36*†

Data presented as mean ± SD; MTH=Muscle Thickness; Q:H MTH Ratio=Quadriceps to Hamstrings MTH Ratio; B:T MTH Ratio=Biceps to Triceps MTH Ratio; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG

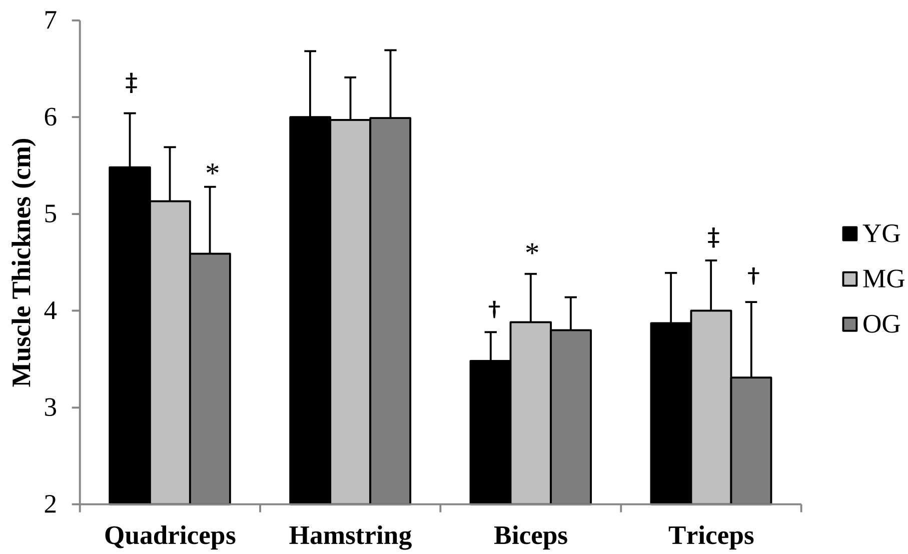

Figure 1. Muscle Thickness
Data presented as mean ± SD; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * *p*≤0.05 from YG; † *p*≤0.05 from MG; ‡ *p*≤0.05 from OG

Strength, Training Volume, and Muscle Quality

One-repetition maximum (1-RM) values are reported in Table 4 and depicted in Figure 2. Leg press 1-RM was significantly greater in the YG compared to the OG (p=0.01) but not the MG (p=0.37), and the MG was not significantly different compared to the OG (p=0.17). For chest press 1-RM, the YG and MG had significantly greater values compared to the OG (p=0.02 and p=0.02) but no difference was found between the YG and MG (p=0.98). The YG was also significantly stronger for the knee extension exercise compared to the OG ($p<0.05$) but no difference was found between the YG and MG or MG and OG. No significant difference was found between age groups for strength for either knee flexion or lat pulldown. The total exercise volume performed during the exercise session was significantly different between age groups with the YG and MG performing a significantly greater amount of work than the OG

($p=0.003$ and $p=0.02$) but no difference was found between the YG and MG ($p=0.63$). No significant differences were found between groups for knee flexion to hamstrings MTH ($p=0.13$), knee extension to quadriceps MTH ratio ($p=0.08$). However, a significant ratio was found when combining leg press, knee extension and knee flexion strength to leg lean tissue ($p<0.001$) such that the YG was greater than the MG ($p<0.001$) and OG ($p<0.001$) but no differences were found between the MG and OG ($p=0.45$). In addition, when comparing total lower body strength (leg press, knee extension and knee flexion) to quadriceps and hamstring MTH, the YG was significantly greater than the OG ($p=0.03$) but no differences were found between the YG and MG ($p=0.86$) or MG and OG ($p=0.08$). Also, knee flexion to knee extension strength was significantly different among groups ($p=0.03$) such that the YG had a lower ratio compared to the OG ($p=0.03$) but no differences were found between YG and MG ($p=0.15$) and MG and OG ($p=0.65$).

Table 4. One-Repetition Maximum

	YG (n=12)	MG (n=14)	OG (n=10)
Leg Press (kg)	151.8 ± 19.8‡	137.6 ± 31.9	117.6 ± 23.5*
Chest Press (kg)	75.8 ± 16.5‡	74.5 ± 16.3‡	55.5 ± 15.2†*
Knee Flexion (kg)	77.6 ± 9.7	76.3 ± 15.7	65.9 ± 8.5
Lat Pulldown (kg)	71.5 ± 10.6	70.3 ± 10.4	61.7 ± 9.5
Knee Extension (kg)	85.7 ± 8.9‡	74.7 ± 17.7	60.5 ± 12.1*
Exercise Volume (kg)	9864.0 ± 1287.4‡	9321.0 ± 1727.3‡	7554.1 ± 1333.7†*
Knee Flexion to Knee Extension Ratio (kg/kg)	0.91 ± 0.14‡	1.04 ± 0.21	1.11 ± 0.14*
Knee Flexion to Ham MTH Ratio (kg/cm)	13.14 ± 2.46	13.66 ± 4.22	11.07 ± 1.53
Knee Extension to Quad MTH Ratio	15.77 ±2.30	14.55 ± 3.04	13.21 ± 2.06
Leg Strength (leg press, knee extension, knee flexion) to Leg Lean Tissue (kg/kg)	17.51 ± 1.45†‡	14.69 ± 1.79*	13.86 ± 1.60*
Leg Strength (leg press, knee extension, knee flexion) to Hamstring and Quadriceps MTH (kg/cm)	27.45 ± 1.96‡	26.65 ± 5.07	23.12 ± 3.49*

Data presented as mean ± SD; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG

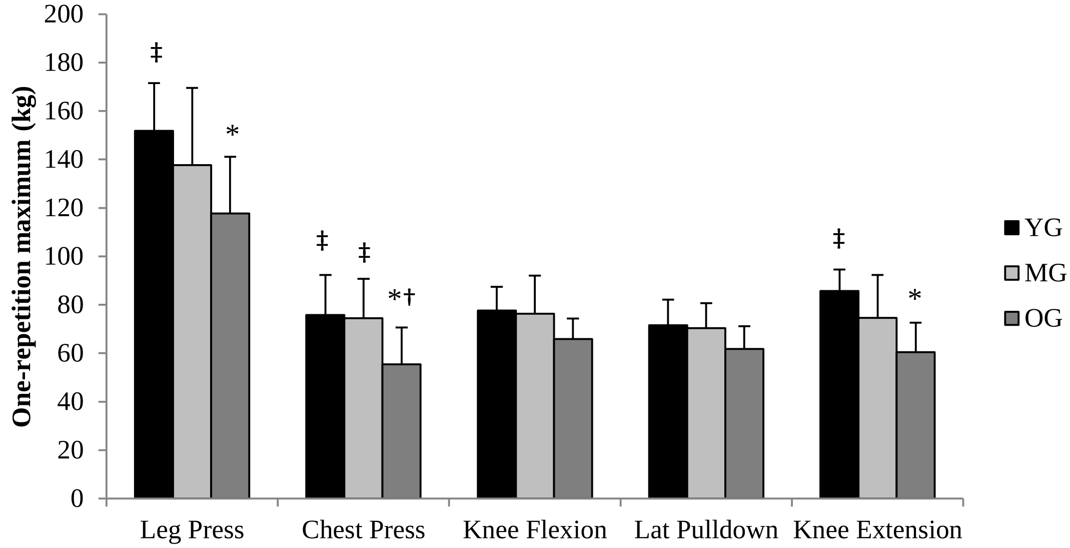

Figure 2. One-Repetition Maximum

Data presented as mean ± SD; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG

Baseline Cardiovascular Comparisons

When comparing pre-exercise and pre-control values using a paired samples t-test, no significance differences were found for peripheral SBP (pSBP), peripheral DBP (pDBP), central SBP (cSBP), central DBP (cDBP), mean arterial pressure (MAP), augmented pressure adjusted for heart rate of 75 beats per minute (AP_75), augmentation index adjusted for a heart rate of 75 bpm (AIx_75), peripheral PWV (pPWV), central PWV (cPWV), forearm blood flow (FBF), forearm vascular conductance (FVC), heart rate (HR), stroke volume index (SV_Index), cardiac output index (Q_Index), or ejection fraction (EF) (all $p>0.05$) for either the YG, MG or OG. Therefore, the values from the two pre-conditions were averaged and a one-way analysis of variance was used to compare baseline differences between groups for each variable. No significant differences were found between groups at baseline for pSBP (p=0.57), pDBP (p=0.051), cDBP (p=0.059), MAP (0.066), pPWV (p=0.052), FBF (p=0.38), FVC (p=0.35), HR (p=0.78), SV_Index (p=0.29), Q_Index (p=0.70), and EF (p=0.058). A significant difference was found between groups for cSBP (p=0.02), AP (p<0.001), AIx (p<0.001), and cPWV (p<0.001). Data are presented in Table 5. Correlations between variables and age are found in Table 6 and graphical representations are found in Figures 3-17.

Table 5. Cardiovascular Baseline Characteristics

	YG	**MG**	**OG**
pSBP (mmHg)	123 ± 9	121 ± 8	125 ± 11
pDBP (mmHg)	71 ± 4	75 ± 7	78 ± 7
cSBP (mmHg)	104 ±7‡	110 ± 8	115 ± 12*
cDBP (mmHg)	72 ± 4	76 ± 7	78 ± 7
MAP (mmHg)	86 ± 5	91 ± 7	94 ± 9
AP_75 (mmHg)	-3.25 ± 2.71‡†	2.46 ± 2.17*	5.35 ± 4.60*
AIx_75 (%)	-10.25 ± 7.25‡†	7.69 ± 6.06*	14.85 ± 11.08*
pPWV (m/s)	7.61 ± 0.61	7.52 ± 0.47	8.29 ± 1.19
cPWV (m/s)	5.92 ± 0.6‡	6.74 ± 3.31‡	8.29 ± 1.13*†
FBF (ml/min/100ml)	2.78 ± 0.86	3.31 ± 2.19	2.45 ± 0.70
FVC (flow/mmHg)	32.40 ± 10.37	36.98 ± 26.11	26.17 ± 6.65
HR (bpm)	57 ± 8	54 ± 10	55 ± 9
SV_Index (ml·beat^{-1})·m^{-2}	44.43 ± 6.55	49.70 ± 8.19	48.6 ± 10.85
Q_Index (l·min^{-1})·m^{-2}	24.90 ± 3.73	26.50 ± 5.29	27.07 ± 9.24
EF (%)	57.58 ± 2.84	61.28 ± 4.43	61.69 ± 5.55

Data presented as mean ± SD; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; peripheral SBP (pSBP); peripheral DBP (pDBP); central SBP (cSBP); central DBP (cDBP); mean arterial pressure (MAP); augmented pressure adjusted for heart rate of 75 beats per minute (AP_75); augmentation index adjusted for a heart rate of 75 bpm (AIx_75); peripheral PWV (pPWV); central PWV (cPWV); forearm blood flow (FBF); forearm vascular conductance (FVC); heart rate (HR); stroke volume index (SV_Index); cardiac output index (Q_Index); or ejection fraction (EF); * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG.

Table 6. Correlations of Cardiovascular Variables with Age

Variable	Pearson Correlation with Age	P-Value
pSBP (mmHg)	0.07	0.67
pDBP (mmHg)	0.38	0.02
cSBP (mmHg)	0.48	<0.01
cDBP (mmHg)	0.37	0.03
MAP (mmHg)	0.40	0.02
AP_75 (mmHg)	0.79	<0.01
AIx_75 (%)	0.81	<0.01
pPWV (m/s)	0.18	0.31
cPWV (m/s)	0.66	<0.01
FBF (ml/min/100ml)	-0.04	0.83
FVC (flow/mmHg)	-0.09	0.60
HR (bpm)	-0.12	0.51
SV_Index $(ml \cdot beat^{-1}) \cdot m^{-2}$	0.23	0.21
Q_Index $(l \cdot min^{-1}) \cdot m^{-2}$	0.14	0.46
EF (%)	0.39	0.03

Peripheral SBP (pSBP); peripheral DBP (pDBP); central SBP (cSBP); central DBP (cDBP); mean arterial pressure (MAP); augmented pressure adjusted for heart rate of 75 beats per minute (AP_75); augmentation index adjusted for a heart rate of 75 bpm (AIx_75); peripheral PWV (pPWV); central PWV (cPWV); forearm blood flow (FBF); forearm vascular conductance (FVC); heart rate (HR); stroke volume index (SV_Index); cardiac output index (Q_Index); or ejection fraction (EF)

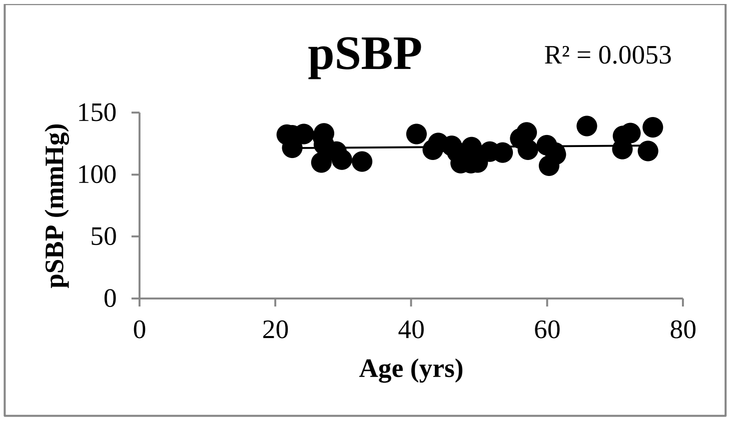

Figure 3. pSBP and Age
pSBP = peripheral systolic blood pressure; yrs = years

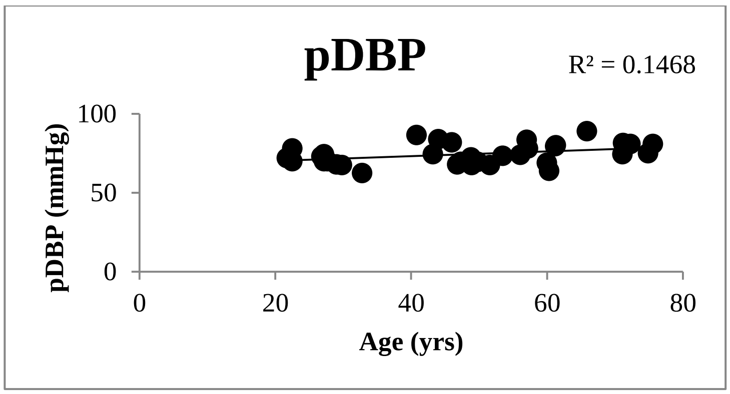

Figure 4. pDBP and Age
pDBP = peripheral diastolic blood pressure; yrs = years

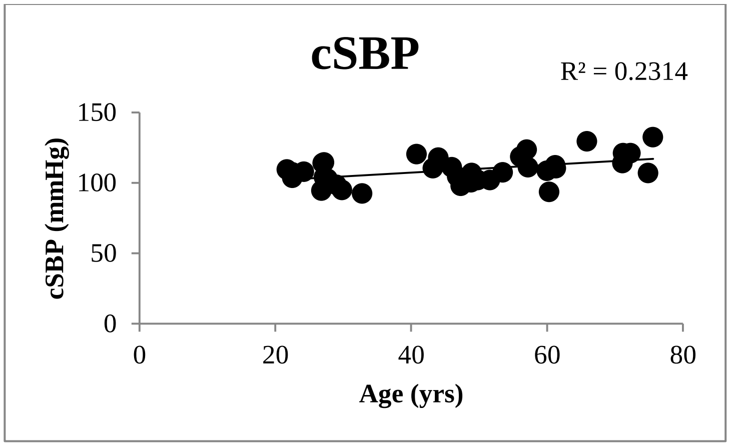

Figure 5. cSBP and Age
cSBP = central systolic blood pressure; yrs = years

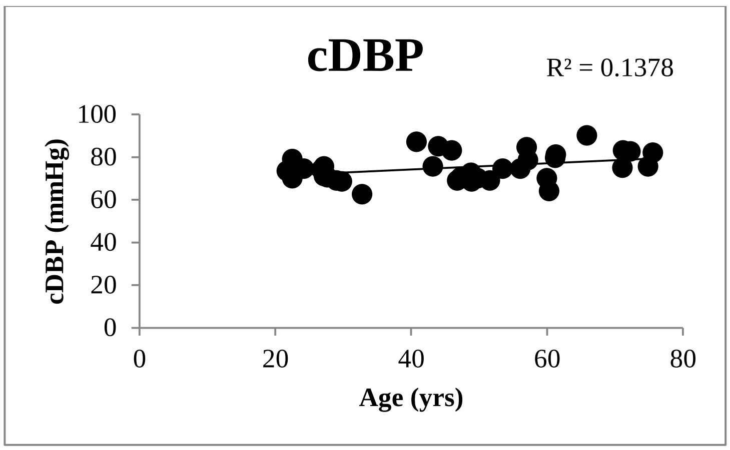

Figure 6. cDBP and Age
cDBP = central diastolic blood pressure; yrs = years

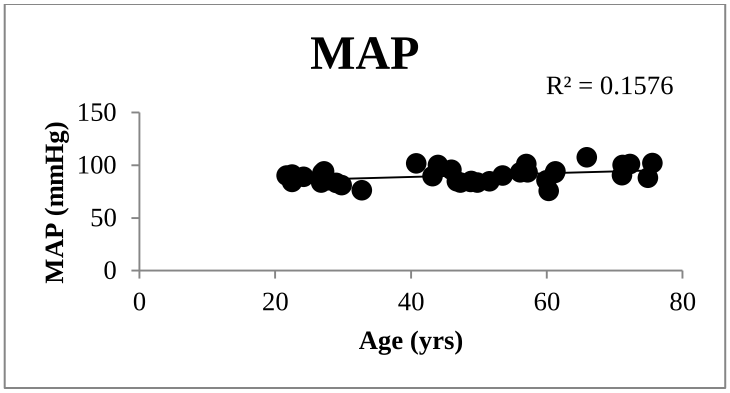

Figure 7. MAP and Age
MAP = mean arterial blood pressure; yrs = years

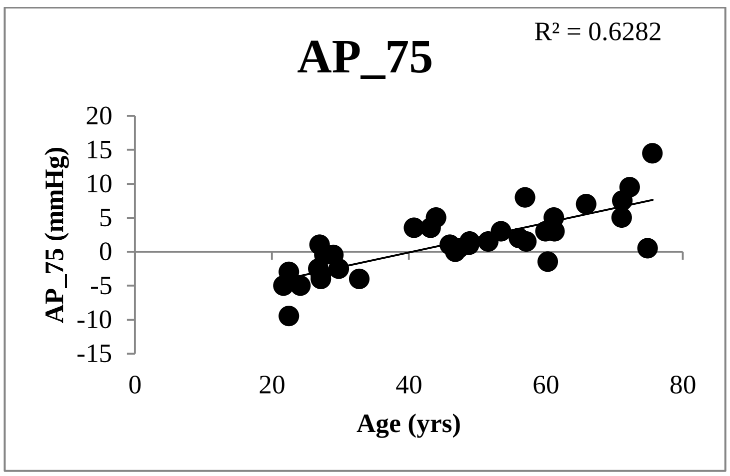

Figure 8. AP_75 and Age
AP_75 = augmented pressure adjusted to a heart rate of 75 bpm; yrs = years

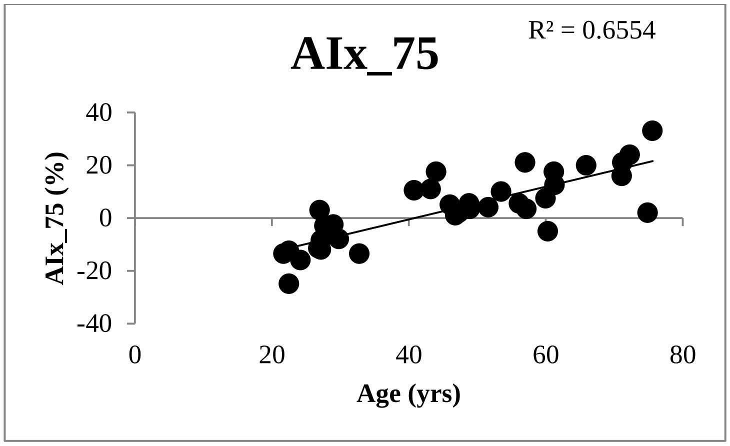

Figure 9. AIx_75 and Age
AIx_75 = augmentation index adjusted to a heart rate of 75 bpm; yrs = years

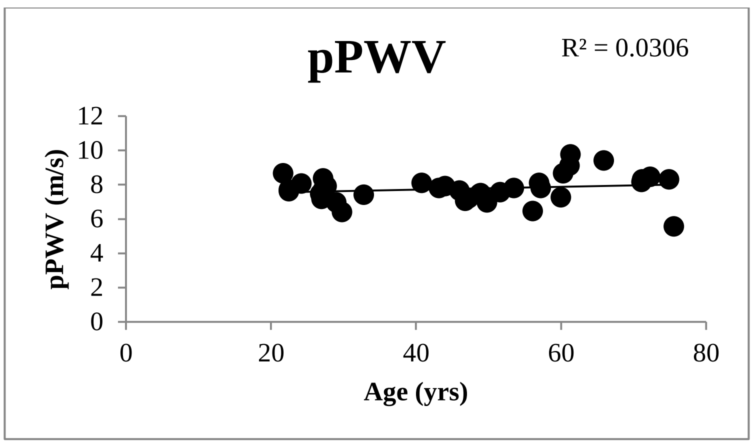

Figure 10. pPWV and Age
pPWV = peripheral pulse wave velocity; yrs = years

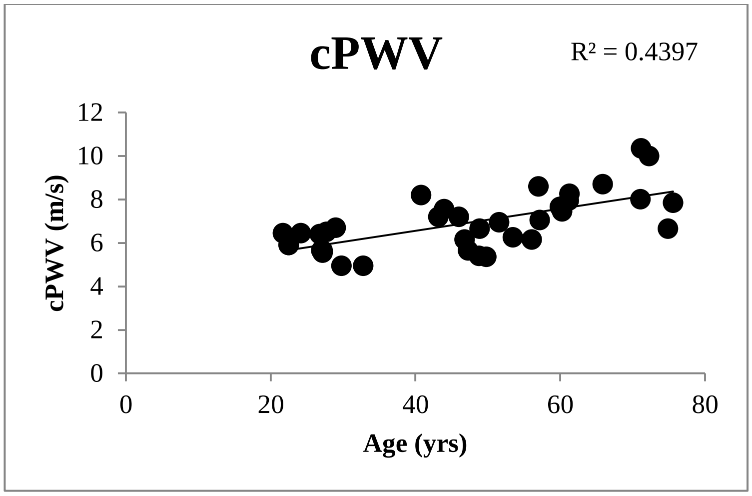

Figure 11. cPWV and Age
cPWV = central pulse wave velocity; yrs = years

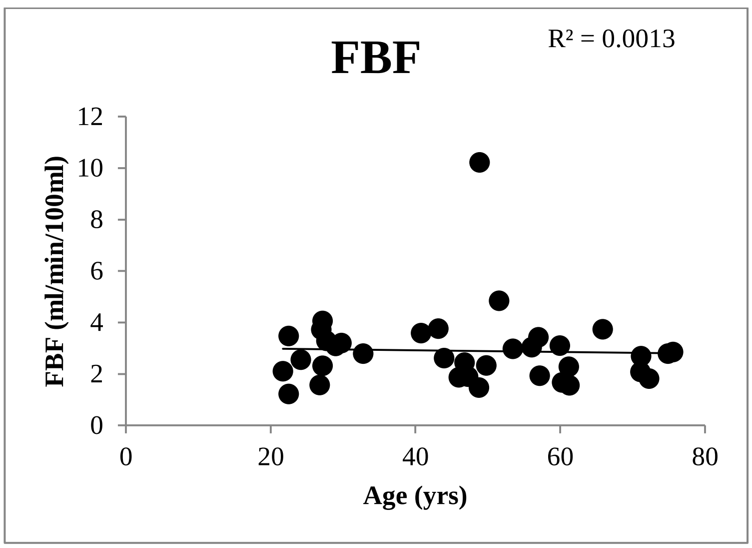

Figure 12. FBF and Age
FBF= forearm blood flow; yrs = years

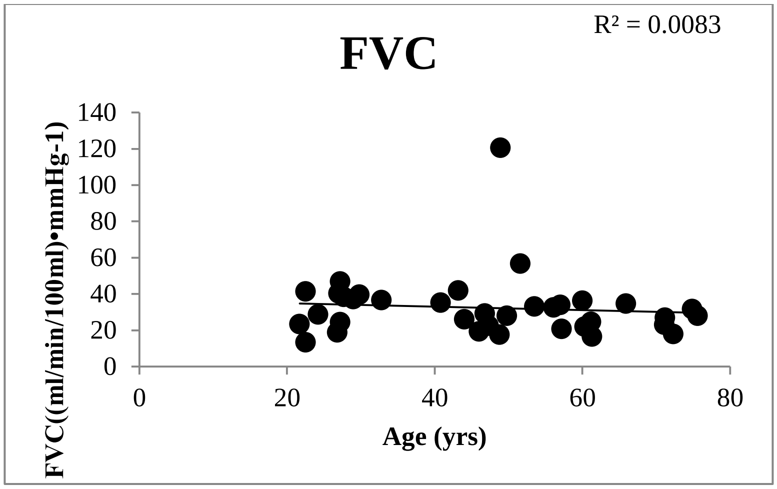

Figure 13. FVC and Age
FVC= forearm vascular conductance; yrs = years

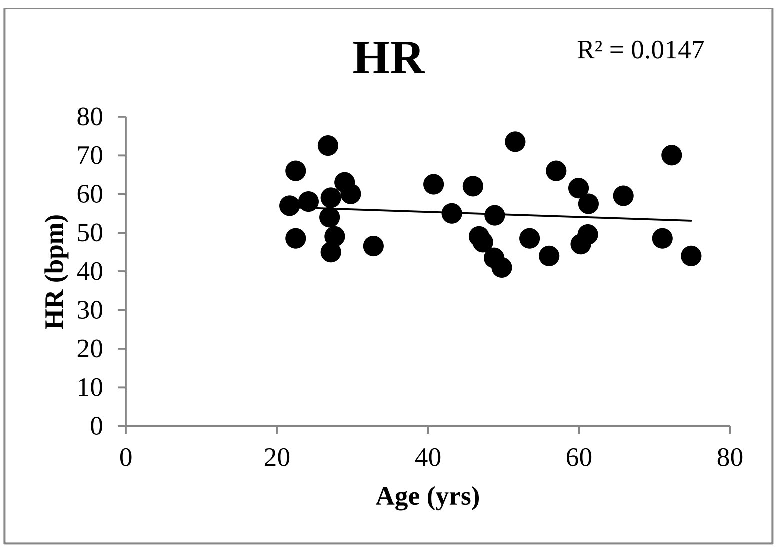

Figure 14. HR and Age
HR= heart rate; yrs = years

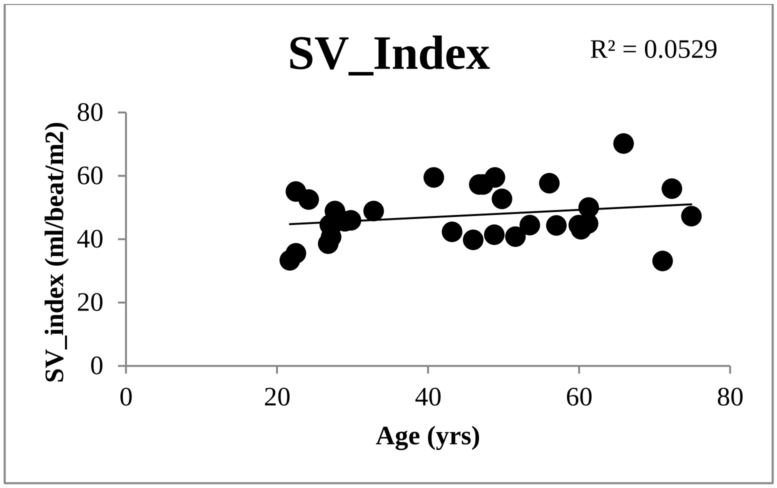

Figure 15. SV_Index and Age
SV_Index= stroke volume index; yrs = years

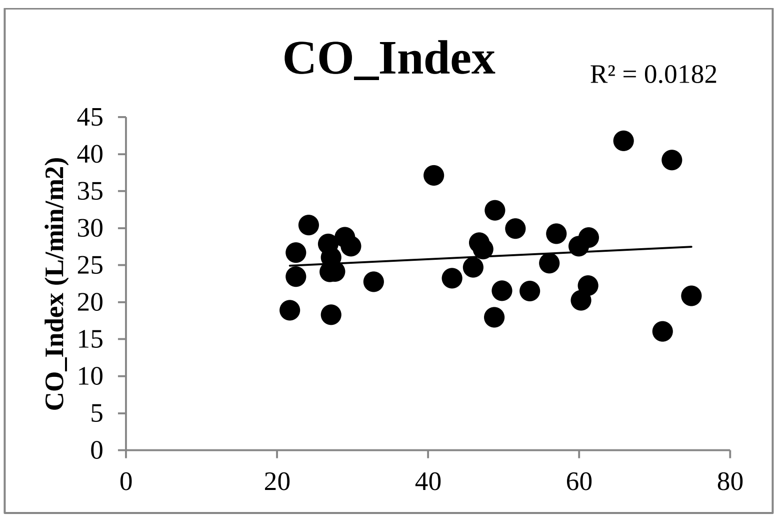

Figure 16. CO_Index and Age
CO_Index= Cardiac output index; yrs = years

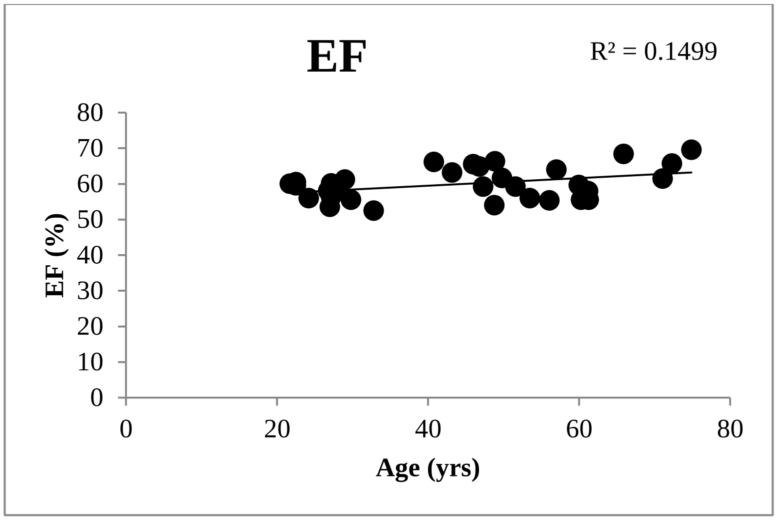

Figure 17. EF and Age
EF= ejection fraction; yrs = years

Peripheral SBP

The reliability of hemodynamic measures was calculated from pre-exercise and pre-control conditions. The ICC for pSBP was 0.75, the SEM was 4.7 mmHg and MD 12.9 mmHg. Data are presented in Table 7.

Table 7. Peripheral SBP

	Exercise[#]			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	124 ± 9	132 ± 13	8 ± 8	122 ± 10	120 ± 11	-2 ± 4
MG (n=14)	120 ± 8	125 ± 8	5 ± 5	121 ± 9	122 ± 9	1 ± 7
OG (n=10)	124 ± 12	130 ± 11	5 ± 6	125 ± 10	129 ± 16	4 ± 8

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq .05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

A two-way repeated measures analysis with the change scores from pre to post revealed no condition*group interaction (p=0.07). A significant condition main effect was found (p=0.003), such that the exercise condition had significantly larger changes in pSBP compared to the control condition (6 ± 7 vs. 1 ± 6 mmHg) but there was no significant group main effect between groups (YG: 3 ± 8 vs. MG: 3 ± 8 mmHg vs. OG: 5 ± 9 mmHg, p=0.63).

Peripheral DBP

The $ICC_{3,1}$ for pDBP was 0.78, the SEM was 2.9 mmHg, and the MD was 8.2 mmHg. Data are presented in Table 8.

Table 8. Peripheral DBP

	Exercise#			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	72 ± 5	67 ± 9	-5 ± 6	70 ± 5	72 ± 7	1 ± 5
MG (n=14)	75 ± 6	69 ± 6	-6 ± 5	75 ± 8	77 ± 8	1 ± 5
OG (n=10)	77 ± 7	74 ± 7	-3 ± 5	78 ± 8	81 ± 9	4 ± 3

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no condition*group interaction (p=0.97) was found. A significant condition main effect was found (p<0.001), such that the exercise condition had significantly larger changes in pDBP compared to the control condition (-5 ± 6 vs. 2 ± 4 mmHg). No significant group main effect was found between groups (YG: -2 ± 5 vs. MG: -2 ± 5 mmHg vs. OG: 0 ± 6 mmHg, p=0.18).

Central SBP

The $ICC_{3,1}$ for cSBP was 0.82, the SEM was 3.8 mmHg and the MD was 10.6 mmHg. Data are presented in Table 9.

Table 9. Central SBP

	Exercise[¥]			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	104 ± 7	107 ± 10	2 ± 7	103 ± 9	102 ± 9	-2 ± 4[‡]
MG (n=14)	110 ± 7	108 ± 6	-2 ± 5	110 ± 10	110 ± 10	1 ± 6
OG (n=10)	115 ± 13	113 ± 10	-2 ± 7	115 ± 11	121 ± 16	5 ± 7[*]

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, a significant condition*group interaction (p=0.02) was found but both the condition main effect and group main effect were not significant (p=0.23, p=0.42). Follow-up analysis found no significant difference between the exercise and control conditions for the YG (2 ± 7 vs. -2 ± 4 mmHg, p=0.052), MG (-2 ± 5 vs. 1 ± 6 mmHg, p=0.16), and OG (-2 ± 7 vs. 5 ± 7 mmHg, p=0.13). For the exercise condition, a one-way ANOVA across group was not significant (p=0.18), but a significant one-way ANOVA across group for the control condition was found (p=0.04). The YG had significantly lower cSBP than the OG group (p=0.03) but no significant differences were found between the YG vs. MG (p=0.54) or MG vs. OG (p=0.21).

Central DBP

The $ICC_{3,1}$ for cDBP was 0.79, the SEM was 3.6 mmHg and the MD was 9.9 mmHg. Data are presented in Table 10.

Table 10. Central DBP

	Exercise#			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	73 ± 5	69 ± 9	-4 ± 7	71 ± 9	72 ± 7	1 ± 5
MG (n=14)	76 ± 6	71 ± 6	-5 ± 5	76 ± 10	77 ± 8	1 ± 4
OG (n=10)	78 ± 8	76 ± 7	-2 ± 6	78 ± 11	82 ± 9	4 ± 3

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no significant condition*group interaction (p=0.91) was found. A significant condition main effect was found (p<0.001) such that the exercise condition had significantly greater changes in cDBP compared to the control condition (-4 ± 6 vs. 2 ± 4 mmHg) but no significant group main effect was found between groups (YG: -1 ± 5 vs. MG: -2 ± 5 mmHg vs. OG: 1 ± 6 mmHg, p=0.12).

MAP

The $ICC_{3,1}$ for MAP was 0.81, the SEM was 3.7 mmHg and the MD was 10.2 mmHg. Data are presented in Table 11.

Table 11. MAP

	Exercise#			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	87 ± 5	85 ± 10	-2 ± 7	86 ± 6	85 ± 8	0 ± 4
MG (n=14)	91 ± 6	87 ± 6	-4 ± 4	91 ± 8	92 ± 8	1 ± 5
OG (n=10)	94 ± 11	92 ± 8	-2 ± 7	94 ± 9	98 ± 12	4 ± 4

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no condition*group interaction (*p*=0.44) was found. A significant condition main effect was found (*p*=0.004) such that the exercise condition had significantly larger changes in MAP compared to the control condition (-3 ± 6 vs. 2 ± 5 mmHg) but no significant group main effect was found between groups (YG: -1 ± 6 vs. MG: -2 ± 5 mmHg vs. OG: 1 ± 6 mmHg, *p*=0.13).

AP and AIx (Adjusted for HR at 75 bpm)

The $ICC_{3,1}$ for AP was 0.88, the SEM was 1.67 mmHg and the MD was 4.62 mmHg. Data are presented in Table 12.

Table 12. Augmentation Pressure

	Exercise[¥§]			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	-3.17 ± 2.44	0.50 ± 2.07	3.67 ± 2.77[a†‡]	-3.33 ± 3.28	-2.92 ± 2.81	0.42 ± 1.98[b]
MG (n=13)	2.54 ± 2.22	2.54 ± 3.93	0.00 ± 3.51[*]	2.38 ± 2.82	2.23 ± 2.89	-0.15 ± 1.46
OG (n=10)	5.70 ± 4.99	5.00 ± 4.35	-0.70 ± 2.83[*]	5.00 ± 4.55	6.00 ± 4.47	1.00 ± 1.63

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; # *p*≤0.05 condition main effect; § *p*≤0.05 group main effect; ¥ *p*≤0.05 interaction effect; * *p*≤0.05 from YG; † *p*≤0.05 from MG; ‡ *p*≤0.05 from OG; [a] *p*≤0.05 from control condition; [b] *p*≤0.05 from exercise condition.

Performing a two-way repeated measures analysis with the change scores from pre to post, a significant condition*group interaction (*p*=0.005) and group main effect (*p*=0.02) were found but the condition main effect was not significant (*p*=0.32). Follow-up analysis found a significant difference between the exercise and control condition for the YG (4 ± 3 vs. 0 ± 2 mmHg, *p*=0.01) but not the MG (0 ± 4 vs. 0 ± 2 mmHg, *p*=0.88) or OG (-1 ± 3 vs. 1 ± 2 mmHg, p=0.22). In the control condition, a one-way ANOVA across group was not significant (p=0.29), but a significant difference in augmentation pressure across groups in the exercise condition was found (p=0.003). The YG had significantly greater augmentation pressure than the OG group (p=0.01) and MG (p=0.006) but no significant differences were found between the MG vs. OG (p=0.84).

The $ICC_{3,1}$ for AIx was 0.89, the SEM was 4.46 mmHg and the MD was 12.37 mmHg. Data are presented in Table 13.

Table 13. Augmentation Index

	Exercise[¥§]			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	-9.92 ± 6.82	1.42 ± 6.19	11.33 ± 8.25 [a†‡]	-10.58 ± 8.98	-10.42 ± 8.78	0.17 ± 6.52 [b]
MG (n=13)	7.92 ± 6.24	6.77 ± 10.41	-1.15 ± 8.43 [*]	7.46 ± 7.90	7.00 ± 9.06	-0.46 ± 4.46
OG (n=10)	15.20 ± 11.74	12.00 ± 9.13	-3.20 ± 6.48 [*]	14.50 ± 11.05	16.40 ± 10.28	1.90 ± 3.51

Data presented as mean ± SD; Units are in %; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, significant condition*group interaction (p<0.001) and group main effect (p=0.006) were found, but the condition main effect was not significant (p=0.20). Follow-up analysis found a significant difference between the exercise and control condition for the YG (11 ± 8 vs. 0 ± 7%, p<0.001) but not the MG (-1 ± 8 vs. -1 ± 5%, p=0.79) and OG (-3 ± 7 vs. 2 ± 4%, p=0.08). In the control condition, a one-way ANOVA across groups was not significant (p=0.38), but a significant difference in AIx across groups in the exercise condition was found (*p*<0.001). The YG had a significantly larger AIx change than the OG group (*p*=0.001) and MG group (*p*<0.001) but no significant difference was found between the MG vs. OG (*p*=0.81).

Peripheral PWV

Peripheral PWV from pre-exercise to pre-control time points yielded an $ICC_{3,1}$ of 0.31, a SEM of 0.81 m/s and a MD of 2.24 m/s. No significant relationship was found between total bone free lean tissue and pPWV (r=0.006, *p*=0.97). Data are presented in Table 14.

Table 14. Peripheral PWV

	Exercise#			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	7.8 ± 0.5	7.1 ± 0.7	-0.6 ± 0.7	7.5 ± 1.0	7.9 ± 1.3	0.4 ± 0.9
MG (n=14)	7.5 ± 0.8	7.6 ± 1.3	0.1 ± 1.1	7.6 ± 0.7	8.0 ± 0.8	0.4 ± 1.0
OG (n=10)	8.1 ± 1.5	8.2 ± 1.2	0.0 ± 1.2	8.4 ± 1.3	8.5 ± 0.6	0.1 ± 1.1

Data presented as mean ± SD; Units are in m/s; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * *p*≤0.05 from YG; † *p*≤0.05 from MG; ‡ *p*≤0.05 from OG; # *p*≤0.05 condition main effect; § *p*≤0.05 group main effect; ¥ *p*≤0.05 interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no significant condition*group interaction (*p*=0.13) was found. A significant condition main effect was found (*p*=0.03), such that the exercise condition had a significantly lower pPWV when compared to the control condition (-0.2 ± 1.0 vs. 0.3 ± 1.0 m/s), but no significant group main effect was found between groups (YG: -0.1 ± 1.3 vs. MG: 0.3 ± 1.2 vs. OG: 0.1 ± 1.5 m/s, *p*=0.52).

When examining individual changes, the YG had 10 participants who had decreases in peripheral PWV and 2 who exhibited increased pPWV following the exercise condition (Figure 18). In the control condition, 6 participants increased pPWV and 6 participants decreased pPWV. However, none of the individual changes exceeded the MD of 2.24 m/s.

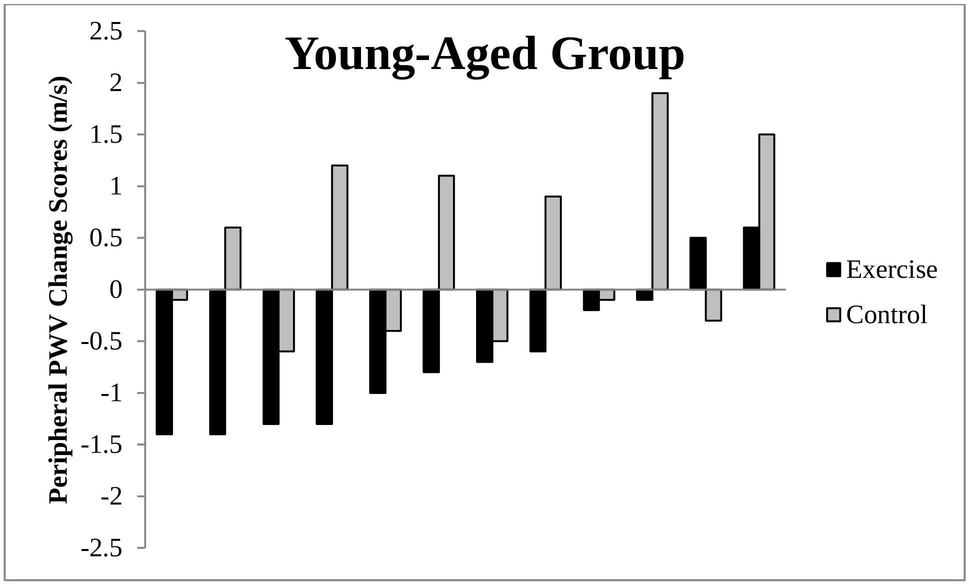

Figure 18. YG Peripheral PWV Individual Responses
Data presented as post-pre values for exercise and control conditions; PWV = pulse wave velocity.

The MG had 8 participants who had decreases in pPWV and 6 who increased pPWV following the exercise condition (Figure 19). In the control condition, 8 participants increased pPWV and 6 participants decreased pPWV. However, none of the individual changes exceeded the MD of 2.24 m/s.

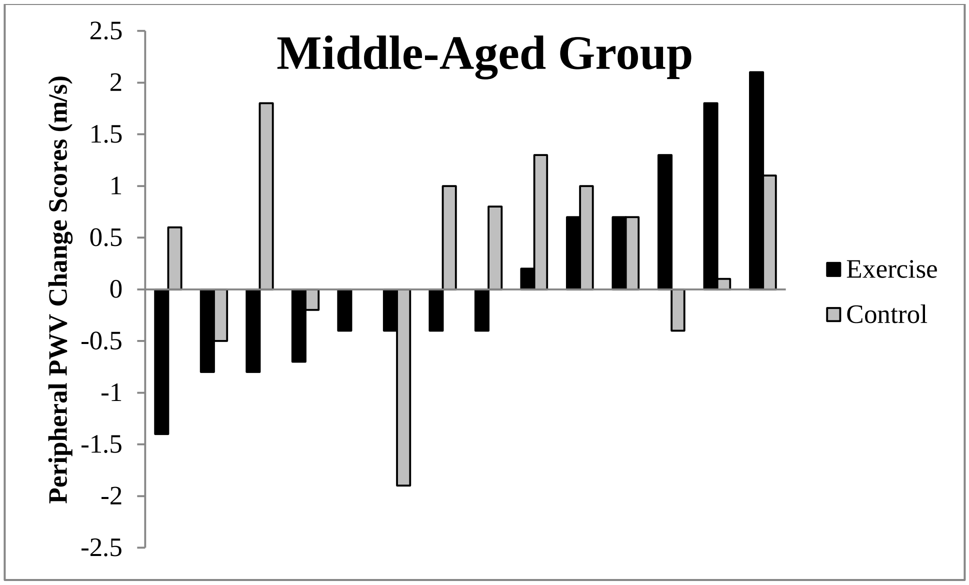

Figure 19. MG Peripheral PWV Individual Responses
Data presented as post-pre values for exercise and control conditions; PWV = pulse wave velocity.

The OG had 6 subjects who had decreases in pPWV and 4 who increased pPWV following the exercise condition (Figure 20). In the control condition, 7 participants increased pPWV and 3 participants decreased pPWV. Only 1individual exceeded the MD of 2.24 m/s.

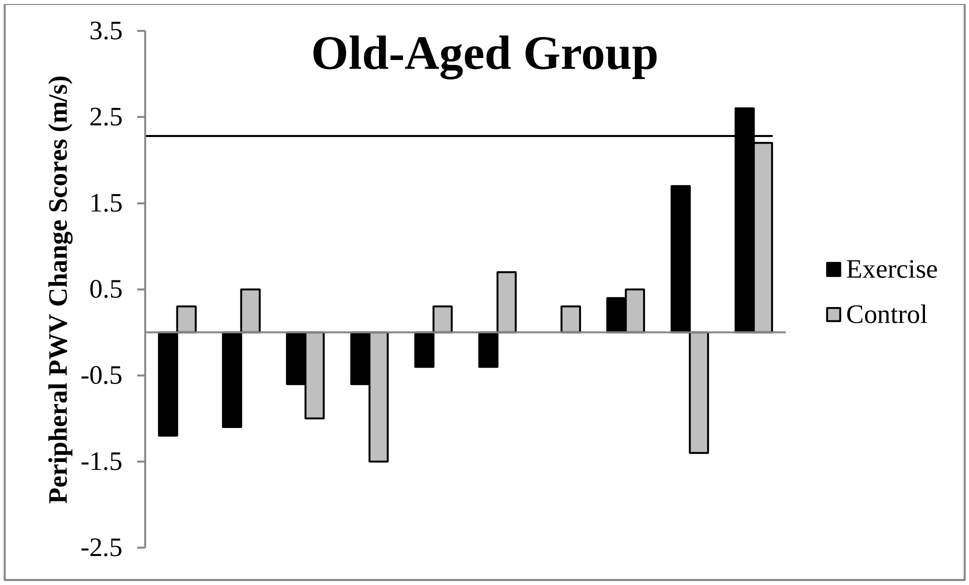

Figure 20. OG Peripheral PWV Individual Responses
Data presented as post-pre values for exercise and control conditions; PWV = pulse wave velocity.

Central PWV

Central PWV from pre-exercise to pre-control time points had an $ICC_{3,1}$ of 0.86, SEM of 0.50 m/s and a MD of 1.40 m/s. No significant relationship was found between cPWV and total bone free lean tissue mass (r=-0.06, *p*=0.75). The total volume of work performed and changes in cPWV after exercise were not related before (r=0.10, *p*=0.56) or after controlling for differences in age (r=-0.04, *p*=0.82). Data are presented in Table 15.

Table 15. Central PWV

	Exercise			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)*	6.0 ± 0.7	6.5 ± 1.1	0.53 ± 0.74	5.9 ± 0.6	5.8 ± 0.5	-0.06 ± 0.52
MG (n=14)	6.6 ± 0.8	6.9 ± 1.3	0.31 ± 0.83	6.9 ± 1.3	7.0 ± 1.0	0.05 ± 0.96
OG (n=10)	8.3 ± 1.5	8.3 ± 1.8	0.04 ± 0.85	8.3 ± 0.9	7.9 ± 1.3	-0.45 ± 0.99

Data presented as mean ± SD; Units are in m/s; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no condition*group interaction (p=0.81), condition main effect (p=0.054) or group main effect (p=0.10) were found. When examining individual changes, the YG had 8 participants who had increase in cPWV and 4 who decreased cPWV following the exercise condition (Figure 21). In the control condition, 4 participants increased cPWV and 8 participants decreased cPWV. Only 2 people in the exercise condition exceeded the MD of 1.40 m/s.

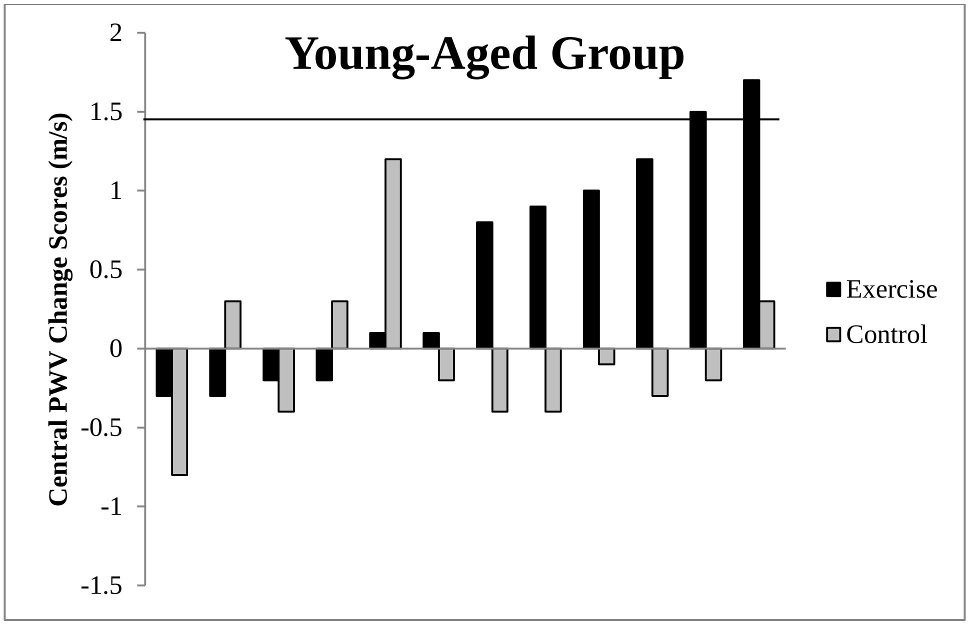

Figure 21. YG Central PWV Individual Responses
Data presented as post-pre values for exercise and control conditions; PWV = pulse wave velocity

In the MG, 8 participants had an increase in cPWV and 6 had a decrease in cPWV following the exercise condition (Figure 22). In the control condition, 8 participants increased cPWV and 6 participants decreased cPWV. Only 2 people in the exercise condition and 2 people in the control condition exceeded the MD of 1.40 m/s.

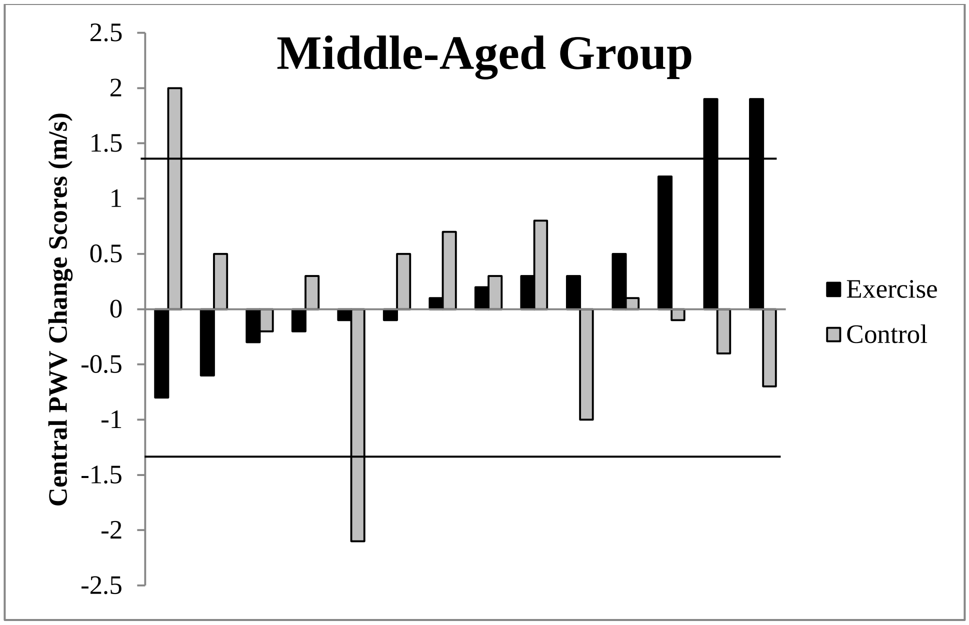

Figure 22. MG Central PWV Individual Responses
Data presented as post-pre values for exercise and control conditions; PWV = pulse wave velocity

In the OG, 5 participants had an increase in cPWV and 5 had a decrease in cPWV following the exercise condition (Figure 23). In the control condition, 4 participants increased cPWV and 6 participants decreased cPWV. Only 2 people in the control condition exceeded the MD of 1.40 m/s.

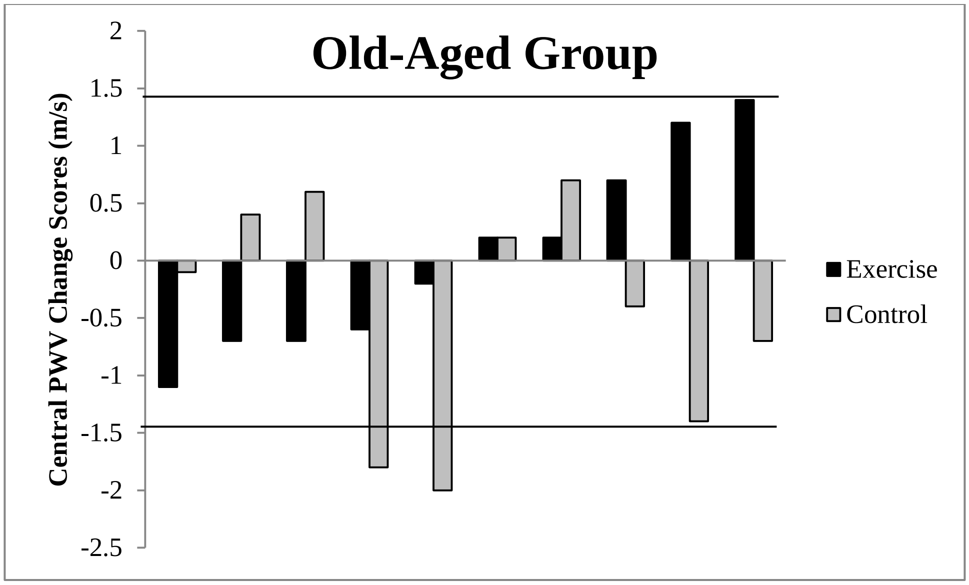

Figure 23. OG Central PWV Individual Responses
Data presented as post-pre values for exercise and control conditions; PWV = pulse wave velocity

Heart Rate

Heart rate from pre-exercise to pre-control time points had an $ICC_{3,1}$ of 0.86, a SEM of 3 bpm and a MD of 10 bpm. Data are presented in Table 16.

Table 16. Heart Rate

	Exercise$^{¥§}$			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	58 ± 9	86 ± 12	28 ± 13^{a†‡}	56 ± 8	54 ± 7	-2 ± 4^{b}
MG (n=14)	54 ± 10	69 ± 14	15 ± 9^{a*}	53 ± 11	50 ± 8	-4 ± 5^{b}
OG (n=10)	55 ± 9	70 ± 18	15 ± 12^{a*}	54 ± 10	51 ± 10	-3 ± 1^{b}

Data presented as mean ± SD; Units are in mmHg; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; ^{a} $p \leq 0.05$ from control condition; ^{b} $p \leq 0.05$ from exercise condition.

Performing a two-way repeated measures analysis with the change scores from pre to post, a significant condition*group interaction (p=0.033) and group main effect (p=0.015) were found but the condition main effect was not significant (p<0.001).

Follow-up analysis found a significant difference between the exercise and control condition for the YG (28 ± 13 vs. -2 ± 4 bpm, $p<0.001$), the MG (15 ± 9 vs. -4 ± 5 bpm, $p<0.001$), and OG (15 ± 12 vs. -3 ± 1 bpm, $p=0.005$). In the control condition, a one-way ANOVA across group was not significant ($p=0.36$), but there was a significant one-way ANOVA across groups in the exercise condition ($p=0.016$). Heart rate for the YG was significantly greater than the OG group ($p=0.027$) and MG group ($p=0.047$) but no significant difference was found between the MG vs. OG ($p=0.99$).

Stroke Volume Index

Stroke volume index from pre-exercise to pre-control time points had an $ICC_{3,1}$ of 0.67, a SEM of 5 ml/beat/m^2 and a MD of 14 ml/beat/m^2. Data are presented in Table 17.

Table 17. Stroke Volume Index

	Exercise			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	45 ± 8	43 ± 6	-2 ± 7	44 ± 7	46 ± 6	3 ± 6
MG (n=12)	48 ± 9	49 ± 9	1 ± 8	52 ± 9	51 ± 10	-1 ± 3
OG (n=8)	49 ± 9	49 ± 14	0 ± 9	48 ± 14	48 ± 10	-1 ± 9

Data presented as mean ± SD; Units are in (ml·beat^{-1})·m^{-2}; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p\leq0.05$ from YG; † $p\leq0.05$ from MG; ‡ $p\leq0.05$ from OG; # $p\leq0.05$ condition main effect; § $p\leq0.05$ group main effect; ¥ $p\leq0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no significant condition*group interaction ($p=0.16$), group main effect ($p=0.99$) or condition main effect ($p=0.57$) were found.

Cardiac Output Index

Cardiac output index from pre-exercise to pre-control time points had an $ICC_{3,1}$ of 0.73, a SEM of 3.0 $ml/min/m^2$ and a MD of 8.2 $ml/min/m^2$. Data are presented in Table 18.

Table 18. Cardiac Output Index

	Exercise$^{\#}$			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	2.6 ± 0.4	3.7 ± 0.8	1.1 ± 0.7	2.4 ± 0.5	2.5 ± 0.5	0.1 ± 0.4
MG (n=12)	2.6 ± 0.6	3.3 ± 0.7	0.7 ± 0.5	2.7 ± 0.5	2.5 ± 0.6	-0.2 ± 0.2
OG (n=8)	2.7 ± 0.8	3.5 ± 1.5	0.8 ± 0.9	2.7 ± 1.1	2.5 ± 0.9	-0.2 ± 0.5

Data presented as mean ± SD; Units are in $[(l•min^{-1})•m^{-2}]$; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, a significant condition main effect ($p<0.001$) was found but the condition*group interaction ($p=0.95$) and group main effect ($p=0.11$) were not significant. Follow-up analysis found a significant difference between the exercise and control condition collapsed across groups (8.9 ± 1.3 vs. -1.0 ± 0.7 $(l•min^{-1})•m^{-2}$; $p<0.001$).

Ejection Fraction

Ejection fraction from pre-exercise to pre-control time points had an $ICC_{3,1}$ of 0.41, SEM of 4.08% and a MD of 11.30%. Data are presented in Table 19.

Table 19. Ejection Fraction

	Exercise			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	59 ± 3	60 ± 4	1 ± 3	57 ± 4	59 ± 3	3 ± 4
MG (n=12)	60 ± 6	62 ± 7	2 ± 5	63 ± 5	63 ± 4	0 ± 5
OG (n=8)	62 ± 7	64 ± 6	2 ± 5	62 ± 6	62 ± 7	1 ± 7

Data presented as mean ± SD; Units are expressed as %; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect.

Performing a two-way repeated measures analysis with the change scores from pre to post, no significant condition*group interaction (p=0.41), group main effect (p=0.88) or condition main effect (p=0.59) was found.

Forearm Blood Flow (FBF)

The $ICC_{3,1}$ for FBF was 0.69, the SEM was 1.30 ml/min/100ml and the MD was 3.61 ml/min/100ml. Data are presented in Table 20.

Table 20. Forearm Blood Flow

	Exercise¥#			Control		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	2.54 ± 0.71	5.82 ± 0.74	3.28 ± 0.97 [a†]	3.01± 1.26	2.40 ± 0.63	-3.42 ± 0.94 [b]
MG (n=14)	3.63 ± 2.94	4.90 ± 2.28	1.27 ± 1.87 [a*]	2.99 ± 1.51	2.42 ± 0.65	-2.49 ± 1.88 [b]
OG (n=10)	2.44 ± 0.78	4.65 ± 1.87	2.21 ± 1.68 [a]	2.46 ± 0.71	2.06 ± 0.47	-2.59 ± 1.63 [b]

Data presented as mean ± SD; Units are in ml/min/100ml; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; # $p \leq 0.05$ condition main effect; § $p \leq 0.05$ group main effect; ¥ $p \leq 0.05$ interaction effect; * $p \leq 0.05$ from YG; † $p \leq 0.05$ from MG; ‡ $p \leq 0.05$ from OG; [a] $p \leq 0.05$ from control condition; [b] $p \leq 0.05$ from exercise condition.

Performing a two-way repeated measures analysis with the change scores from pre to post, a significant condition*group interaction (p=0.026) and condition main effect (p<0.001) were found but the group main effect was not significant (p=0.25).

Follow-up analysis found a significant difference between the exercise and control condition for the YG (3.28 ± 0.97 vs. -3.42 ± 0.94, p<0.001), the MG (1.27 ± 1.87 vs. -2.5 ± 1.88, *p*<0.001) and the OG (2.21 ± 1.68 vs. -2.59 ± 1.63, *p*=0.001). In the control condition, a one-way ANOVA across groups was not significant (*p*=0.28), but a significant one-way ANOVA across groups in the exercise condition was found (*p*<0.01). The YG had significantly greater FBF than the MG group (*p*=0.007) and but no significant differences were found between the MG vs. OG (*p*=0.33) and YG vs. OG (*p*=0.26).

Forearm Vascular Conductance (FVC)

The $ICC_{3,1}$ for FVC was 0.69, the SEM was 13.03 and the MD was 36.12. Data are presented in Table 21.

Table 21. Forearm Vascular Conductance

	Exercise[¥#§]			**Control**		
	Pre	Post	Δ	Pre	Post	Δ
YG (n=12)	29.52 ± 8.81	69.72 ± 13.30	40.20 ± 13.50[a†]	35.28 ± 14.78	28.27 ± 8.82	-7.01 ± 12.50[b]
MG (n=14)	40.72 ± 35.24	56.69 ± 26.03	15.97 ± 22.61[a*]	33.23 ± 17.73	26.63 ± 7.68	-6.61 ± 12.47[b]
OG (n=10)	26.20 ± 7.78	50.61 ± 19.96	24.41 ± 18.87[a]	26.14 ± 6.75	21.42 ± 5.22	-4.71 ± 2.96[b]

Data presented as mean ± SD; Units are in (ml/min/100ml)·$mmHg^{-1}$; YG = Young-aged group; MG = middle-aged group; OG = Old-aged group; # *p*≤0.05 condition main effect; § *p*≤0.05 group main effect; ¥ *p*≤0.05 interaction effect; * *p*≤0.05 from YG; † *p*≤0.05 from MG; ‡ *p*≤0.05 from OG; [a] *p*≤0.05 from control condition; [b] *p*≤0.05 from exercise condition.

Performing a two-way repeated measures analysis with the change scores from pre to post, a significant condition*group interaction (*p*=0.011), condition main effect (*p*<0.001) and group main effect were significant (*p*=0.048). Follow-up analysis revealed a significant difference between the exercise and control condition for the YG (40.20 ± 13.50 vs. -7.01 ± 12.50 (ml/min/100ml)mmHg^{-1}, $p<0.001$), the MG (15.97 ± 22.62 vs. -6.61 ± 12.47 (ml/min/100ml)mmHg^{-1}, $p=0.001$) and the OG (24.41 ± 18.87 vs. -4.71 ± 2.96 (ml/min/100ml)mmHg^{-1}, $p=0.001$). In the control condition, a one-way ANOVA across groups was not significant ($p=0.87$), but a one-way ANOVA across groups in the exercise condition was significant ($p<0.01$). The YG had significantly greater FVC than the MG group ($p=0.007$) but no significant difference was found between the MG vs. OG ($p=0.54$) or YG vs. OG ($p=0.14$).

Discussion

Main Findings

The following are the main findings from this study:

1.) In recreationally active men, no significant differences in body composition measures were found between age groups using DXA; however, using ultrasound a significant difference in site-specific muscle loss for the anterior thigh was noted in the OG compared to the YG.

2.) At rest, the OG had significantly higher central blood pressures compared to the YG, but after performing moderate resistance exercise, no significant differences were found between age groups in blood pressure responses for either central or peripheral blood pressures.

3.) Augmentation pressure and augmentation index were significantly elevated after exercise when compared to the control condition only in the YG.

4.) Despite significantly lower central arterial stiffness at rest in the YG compared to the OG, no significant increases in central arterial stiffness after exercise were found in any group when compared to the control condition.

5.) Heart function parameters were similar among all age groups at rest, but after exercise the YG exhibited a significantly greater increase in heart rate compared to the other age groups. However, no significant changes in stroke volume after exercise were noted in any group. Thus, there was a significant increase in cardiac output post-exercise among all groups that was due primarily to the increased heart rate post exercise.

6.) Forearm blood flow/conductance was significantly elevated in all groups post exercise, but the YG had significantly greater increases compared to the MG.

Site-Specific Muscle Loss

With aging, a significant decline in muscle mass occurs particularly in the fifth decade of life (31, 38). However, resistance training attenuates this decline in muscle mass (50). Intriguingly, when examining fat-free mass, body fat% and total bone free lean body mass in this study, no significant differences were found between age groups. Part of the explanation may be that these men were recreationally active, so the declines in the older individuals may not have been as great as expected. Also, the sample size may not have been sufficiently large enough to detect differences between the groups.

Another explanation for these findings may be that some of the differences in skeletal muscle may not have been detected by whole body examination. When examining site-specific differences among age groups, a significant difference was found for several muscle groups. For example, the anterior thigh (quadriceps) was significantly larger by 0.89 cm or 16% in the YG when compared to the OG. Triceps MTH was significantly lower by 0.69 cm or 17% in the OG when compared to the MG. When examining the anterior to posterior MTH ratios, a significantly lower Q:H MTH ratio was noted for the OG compared to the YG, which denotes a loss of quadriceps muscle compared to the hamstring muscle. This is consistent with other literature. For instance, one study found this same pattern of site-specific muscle loss in both Japanese and German men (5). In addition, site-specific muscle loss in the lower body has been found to be more detectable than the total skeletal muscle mass loss (8). Furthermore, site-specific upper body muscle loss is not as prevalent or noticeable as lower body site-specific muscle loss (6). Our results in the upper body, however, did show a difference between the MG and OG with a greater loss of the triceps compared to the biceps muscle. However, when examining individual differences, two participants in the OG had low triceps MTH and due to the small sample size may have had a great influence on the results. Overall, it appears that site-specific MTH measures are noticeably different among age groups and thus could be another assessment tool to determine the severity of muscle loss and what muscle groups to target with exercise.

Peripheral and Central Blood Pressures

Systolic blood pressure is positively associated with age and the prevalence of isolated systolic hypertension (SBP $\geq$ 140 mmHg and DBP $<$ 90 mmHg) accounts for approximately 87% of hypertension cases in older adults (30, 73). One way to prevent and treat high blood pressure is through exercise. Much of the work performed in this area has focused on aerobic exercise to lower blood pressure, but more research is starting to be done investigating how resistance training affects blood pressure. A meta-analysis reported a significant decrease in SBP (3.5 mmHg) and DBP (3.2 mmHg) after chronic resistance training (21). Acute changes in blood pressure following resistance exercise may lead to these chronic changes. However, the acute changes in blood pressure following resistance training have varied. A majority of studies have examined peripheral blood pressures responses while only a few have examined the central blood pressure responses to resistance exercise (24, 93). In addition, a comparison between the age groups of the responses of peripheral and central blood pressures to an acute bout of resistance exercise is lacking in the literature. Therefore, this study provides insight into the effect that age has on both peripheral and central blood pressure responses to an acute bout of resistance exercise.

The results from this study revealed that pSBP increased significantly among all age groups without a significant difference between groups. These changes after exercise were greater than the control condition when averaging the groups together (6 vs. 1 mmHg). This significant increase post-exercise is in agreement with past studies. One study found that after young women performed six upper and lower body exercises at 60% 1-RM (3 sets of 10 repetitions), pSBP was significantly elevated but by 15 minutes it was no longer significantly elevated; however, at an intensity of 80% of 1-RM, pSBP was still significantly elevated 15 minutes post exercise (66). Fahs et al. (29) also noted in young men a significant elevation in peripheral SBP from 123 to 133 mmHg after high-intensity upper body exercise. In contrast, several other studies did not find a significant increase in SBP after resistance exercise. Hill et al. (37) found that, immediately after performing circuit resistance exercise for 4 exercises at 70% 1-RM to failure, SBP dropped by over 22 mmHg but that it returned to baseline by 1 minute and did not change during the next 60 minutes of recovery. Rezk et al. (77) also did not find a significant change in peripheral SBP from pre-values 15 minutes after high-intensity exercise. When examining the peripheral DBP response, this study found a significant decrease post-exercise that was similar across all age groups. Other studies have also revealed a similar phenomenon (29, 37, 77).

Besides investigating how age influenced brachial blood pressure responses, we investigated the response of central blood pressure. This is an important variable to consider, as central blood pressure may better reflect the load on the heart and also correlates with vascular disease and cardiovascular mortality to a greater extent than brachial blood pressures (78, 89). In the current study, cSBP was not elevated after exercise despite a significant elevation in pSBP. In addition, no differences were found between age groups. This finding was somewhat surprising as a previous study found the opposite results. DeVan et al. (24) found that pSBP did not change in young men and women after resistance exercise but cSBP significantly increased immediately after exercise and remained elevated until 30 minutes post exercise. Another study, however, found no significant change in either peripheral or central blood pressures after resistance exercise (93). The different findings between these studies could be, in part, due to differences in exercise intensities (60% 1-RM vs. 75% 1-RM) and sets and reps (2 sets of 15 reps for 8 exercises vs. 1 set to exhaustion for nine exercises). Potentially performing exercises to exhaustion versus a certain number of repetitions could have influenced the response. In our study, the load was a performed at 65% 1-RM, with a target number of repetitions that may not have been great enough to increase the cSBP.

Little is known about how age may influence the acute blood pressure response to resistance exercise. In the current study, no significant difference was found in peripheral or central SBP and DBP among the different age groups. This was contrary to our original hypothesis, suggesting that the OG would have a blunted response. Other literature suggests that a blunted response in blood pressure after resistance exercise would be found. Kawano et al. (40) found a significant attenuation in the rise of SBP during resistance exercise for older subjects when compared to younger adults at the same relative intensity. In addition, this same blunted response was found for SBP when the same absolute intensity was used for each group. A reason for the discrepancy with the current study may be the measurement time points. For instance, in the study by Kawano et al. (40), the researchers used the peak blood pressure response post-exercise to determine the differences in pressure changes among groups and found that by 60 seconds both SBP and DBP had returned to baseline levels. However, in the current study, blood pressure responses were measured at 5 minutes post exercise. Therefore, a greater difference between age groups might have been noted if blood pressure was measured during or immediately after exercise.

Overall, it appears that during resistance exercise recovery, there may be a range of SBP responses that can occur depending on when the measurement is taken and the type of exercises performed. Considering that numerous variables can be manipulated to produce various strength and muscular adaptations, it is not surprising that different studies using various resistance training protocols have produced various cardiovascular responses. This study was unique in that it investigated how individuals of varying age from 20-75 years respond to the same relative resistance training session. Little differences are noted in the blood pressure response to exercise for these different age groups when performing both lower and upper body exercise at 65% 1-RM for 3 sets of 10 reps.

Arterial Stiffness

One of the main goals of this study was to determine how aging affected arterial stiffness after performing a resistance training session. The stiffness of the arteries is indirectly measured through examining augmentation pressure (AP) and augmentation index (AIx). During resting conditions, AP and AIx were significantly greater in the MG and OG when compared to the YG. Interestingly, we found that, after performing a moderate resistance exercise session, both of these indices were significantly increased only in the YG and not the MG or OG. This supports our original hypothesis that a greater amount of arterial stiffness would occur only in the YG and not the MG and OG. The majority of previous research has only examined the young adult population's arterial responses and reported a similar finding. For instance, Fahs et al. (29) had young men perform high-intensity upper body resistance exercise and found that AIx increased from -8% to 11%. Yoon et al. (93) also found that AIx significantly increased from -14% to -0.3% 20 minutes after exercise. One study did find that AIx was not changed in middle-aged women 20-25 minutes after performing leg press exercise (44), although in overweight middle-aged women AIx increased post-exercise (43). These results suggest that young adults may have greater acute changes in AIx post-resistance exercise than middle-aged and older adults.

One of the more common techniques for measuring arterial stiffness is through measuring PWV. The greater the PWV, the stiffer the arteries are. In the current study, the OG had significantly higher cPWV at rest when compared to the YG and MG. However, no significant changes in cPWV occurred for any group when the resistance training session was compared to the control session. This is contrary to our original hypothesis and past research. Typically, a majority of the literature investigating the acute changes in arterial stiffness in young adults reports significant increases post-exercise. One of the first studies to examine this issue found that young adults who performed resistance exercise to failure (75% 1-RM) had significantly decreased arterial compliance and increased β-stiffness index 5-10 minutes and 30 minutes after exercise (24). Supporting this, Heffernan et al. (35) found that cPWV increased from 4.8 to 5.8 m/s. In our study, the YG had a much higher starting cPWV compared to the study by Heffernan et al. (35) (6.0 vs. 4.8 m/s) and this may partially explain why significant increases did not occur in our YG. In addition, Yoon et al. (93) found that young men had a significant increase in cPWV 20 minutes after performing 8 exercises at 60% 1-RM (2 sets of 15 reps).

In the current study, it was found that cPWV changed by 0.5 m/s, 0.3 m/s and 0.0 m/s for the YG, MG and OG respectively, but none of these changes reached statistical significance when compared to the control condition. Interestingly, Collier et al. (19) found an increase in cPWV at 40 and 60 minutes post exercise in young adults but those changes were smaller compared to the current study (0.29 m/s vs. 0.5 m/s) and no control group was included in their study. Differences in the amount of change in arterial stiffness could partly be due to intensity or the total training volume performed. When a low-intensity resistance upper body exercise was performed, carotid compliance increased and β-stiffness index decreased at 30 and 60 minutes post exercise in young adults (72). Therefore, higher intensity exercise may provoke greater acute increases in arterial stiffness than lower intensities. However, this may not be the entire explanation, as one study found that when only one leg performed high-intensity resistance exercise (85% 1-RM), no significant change was found in cPWV but a significant decrease in pPWV occurred (36). One other factor to consider is the volume of exercise performed. In the current study, the YG and MG performed a significantly greater volume of work compared to the OG but volume was not correlated with changes in cPWV. The current literature does not allow a clear conclusion on how training volume and intensities acutely affect arterial stiffness. Studies investigating multiple bouts of different intensities or volume of exercise are needed to clarify how each of these factors could influence the acute effects of resistance training on arterial stiffness and what the long-term consequences may be.

Both AIx and cPWV were not significantly elevated after resistance exercise for either the MG or OG. This appears to be in line with findings from chronic studies. In a meta-analysis, 2 of the 3 training studies measuring arterial stiffness in middle to old-aged adults found no significant change in cPWV after resistance training (60). Multiple physiological changes happen with aging that may partially explain why little response in arterial stiffness is found after resistance training. With aging, there is an increase in arterial stiffness from increased collagen, increased smooth muscle thickness, and increased vascular tone (10, 67). In addition, there is higher sympathetic activity at rest in older individuals but these individuals have a blunted sympathetic response to exercise (65). These various changes with aging would make it less likely for older individuals to experience significant increases in arterial stiffness following a bout of resistance exercise. Part of the reason differences were not found among the age groups for cPWV may be the larger than expected variation within each age group. Another reason for the lack of difference may be that cPWV could have a diurnal pattern. The participants performed each of their respective visits at the same time of day; however, visits varied from the mornings to the afternoons for different participants. It is unlikely that this had a large effect on the results, as cPWV has been shown to not exhibit significant diurnal variation (53).

Peripheral PWV was another variable measured to determine how the peripheral vasculature responded to a resistance training session and if age influenced the response. At rest, no significant differences were found among the YG, MG and OG for pPWV. Also, no significant differences among age groups were found for changes in pPWV after exercise, but a significant decrease in pPWV was found after exercise when compared to the control condition (-0.2 ± 1.0 vs. 0.3 ± 1.0 m/s). Some studies have reported no significant changes in pPWV, while others have reported a significant decrease. Two studies compared resistance exercise to aerobic exercise and found that peripheral PWV was not changed after resistance exercise 20-40 minutes post exercise (19, 35). Interestingly, when only one leg performed resistance exercise, a significant decrease in pPWV was found at 5 minutes and 25 minutes, with pPWV decreasing from 8.7 to 7.5 m/s at 5 minutes post-exercise (36). The authors suggested that this decrease could be due to local factors released from the exercising muscle such as nitric oxide (NO), which improves arterial distensibility (91). However, other local factors may be involved because when NO production is blocked by a nitric oxide synthase blocker, a decrease in peripheral arterial stiffness is still found after aerobic exercise (81). In the current study, the declines in pPWV were relatively small (-0.2 m/s) and may have been due to a whole body exercise routine producing larger amounts of sympathetic activation than a single leg resistance session.

Heart Rate, Stroke Volume, Cardiac Output and Ejection Fraction

Heart rate, stroke volume, cardiac output and ejection fraction are all important physiological measures of heart function. In this study, heart rate increased significantly among all age groups but the greatest increase in heart rate was found in the YG. No significant changes in stroke volume or ejection fraction were found after resistance exercise for any group. There was a significant increase in cardiac output among all groups, but no difference was found between groups. The increase in cardiac output could be contributed to the increased heart rate found in all groups. These findings are similar to other studies examining heart rate and function after resistance exercise. Heart rate has consistently been found to be elevated by 16-20 bpm after resistance training (24, 29, 93) but returns back to baseline levels by 60 minutes (24). When measuring cardiac output and stroke volume in young adults, Rezk et al. (77) noted a decrease in cardiac output after both low and high-intensity resistance exercise that the authors attributed to a decrease in stroke volume. In another study by Rossow et al. (79), no significant changes in cardiac output or stroke volume were found 30 minutes after exercise. In the current study, a significant decline was not found for stroke volume; rather, cardiac output increased. The significantly larger increases in heart rate in the YG compared to the MG and OG could be explained by a decrease in the responsiveness of the heart to sympathetic stimulation in older adults (18). Overall, the heart function is not greatly affected by age after resistance exercise, but a greater responsiveness in heart rate is found in younger individuals.

Forearm Blood Flow and Forearm Vascular Conductance

Finally, a significant increase in forearm blood flow and vascular conductance post-exercise was found for all age groups. However, the YG had significantly greater increases in forearm blood flow and vascular conductance when compared to the MG but not the OG. The increase in forearm blood flow after resistance exercise is quite common in the literature. Collier et al. (19) found that, 40 minutes after resistance exercise, calf blood flow and forearm blood flow significantly increased. Fahs et al. (29) also found that forearm blood flow increased after resistance exercise. Furthermore, middle-aged women also significantly increase forearm blood after resistance exercise (44). The increase in forearm blood flow found among all the groups in this study may be due to increased vasodilators produced from the exercising limb. Transient increases in sheer stress with resistance exercise could release NO and lead to the release of prostaglandins, endothelial derived hyperpolarizing factors, and acetylcholine that could increase local blood flow (45, 59). It is unclear why in this study the YG and OG had similar responses while the MG was less responsive than these other groups. This result is most likely due to the high resting forearm blood flow values in the MG compared to the YG and OG (3.63 vs. 2.54 and 2.44 ml/min/100ml). The high starting value in the MG could have caused a smaller response to be found in this group.

It was hypothesized that the OG would also have decreased responses to exercise in forearm blood flow, but this was not the case. Evidence both contradicts and supports our finding. For instance, Casey et al. (17) found that older adults had a significant attenuation in the forearm blood flow response compared to younger adults when forearm blood flow was measured immediately after forearm contraction. Interestingly, the differences in forearm blood flow responses were no longer present when both age groups had nitric oxide synthase inhibition. This finding suggests that older adults have decreased bioavailability of nitric oxide or decreased responsiveness to nitric oxide. However, other studies failed to find age-associated differences after performing dynamic forearm exercise (26, 39). Therefore, different mechanisms may influence forearm blood flow responses at the rapid onset of exercise vs. during exercise vs. after exercise. Part of the reason differences were not found in this study may be that venous plethysmography may not have been sensitive enough to detect differences between individuals. There was large variability among participants and a fairly low ICC was calculated among the different visits (ICC=0.69). Furthermore, differences may not have been detected due to the timing of the measurement. Forearm blood flow measurements were performed last (~15-20 minutes after exercise). Future studies should employ a simpler protocol of performing upper body exercises and then measuring forearm blood flow at multiple time points to more accurately determine age differences in forearm blood flow. Overall, it appears that all age groups significantly increased forearm blood flow following whole body resistance exercise, with greater changes occurring in the YG and OG when compared to the MG.

Chapter V: Conclusions

Purpose

The purpose of this study was to determine the influence of age on arterial stiffness, AIx, AP, central and peripheral blood pressures, SV, EF, Q, FBF and FVC after an acute bout of moderate resistance exercise (65% 1-RM, 5 exercises, 3 sets of 10 repetitions).

Hypotheses

1. It was hypothesized that between the ages of 18-39 years, a significant increase in cardiovascular measures would be found post-exercise.

Individuals between 18-39 yrs did have a significant increase in pSBP, AP, AIx, HR, Q, FBF, and FVC. However, cSBP, cPWV, SV and EF were not significantly elevated following resistance exercise. In addition, pPWV significantly declined similarly among all age groups.

2. It was hypothesized that, after the age of 40 years, an attenuated response in cardiovascular measures would be observed when compared to individuals younger than 40 years.

After performing resistance exercise a significant attenuation was found for AP, AIx, HR, FBF and FVC. However, no significant differences were found between age groups for pSBP, pDBP, cSBP, cDBP, cPWV, and pPWV.

Subquestion

1. It was hypothesized that greater muscle mass would result in greater increases in arterial stiffness due to an increased load on the arterial system after an acute

bout of resistance exercise, but that arterial stiffness measures would be greater at rest for individuals with smaller muscle mass.

No significant association was found between the amount of muscle mass and arterial stiffness levels.

Strengths and Limitations

Several limitations exist for this study. First, a large age range for each group makes it difficult to exactly decipher at what age differences become apparent. However, it appears that around the age of 40-50 yrs, changes start to become measurable. Another limitation is that the results from this study are limited to recreationally active males and results could be different when examining non-trained, aerobic-trained or resistance-trained individuals. Also, this is an acute study so conclusions cannot be made about chronic adaptations. One limitation that may have affected the results was that participants were tested at different times of the day. However, each individual was tested at the same time of day. Only having one time during the day would have made it very difficult for recruiting and time management of the study due to the great length of time needed for each visit (1 ½ -2 hours).

Some strengths of this study include that it does cover a wide range of ages from 18-75 yrs. Furthermore, it is the first study to examine how age influences multiple cardiovascular measures when participants perform moderate-resistance exercise.

Significance

With aging, there is a substantial decline in muscle mass. Resistance exercise is an effective means to attenuate these declines in muscle mass and function. However, the response of the cardiovascular system, and the vascular system in particular, to resistance training is unclear. Chronic training studies report increases, decreases and no change in arterial stiffness. These studies have consisted of various age groups and different exercise intensities, making it difficult to decipher what variable may be affecting the arterial stiffness adaptations. One way to decipher how these variables may influence the arterial stiffness adaptations to resistance exercise may be to investigate the acute changes in arterial stiffness following resistance exercise. This is the first study to use multiple age groups using the same relative exercise intensity to investigate how an acute bout of resistance exercise changes arterial stiffness.

Conclusions

After performing a resistance training session, younger individuals have an overall greater cardiovascular response compared to middle-aged and older-aged adults. However, when performing moderate resistance exercise, the changes in cPWV do not appear significant for young-aged, middle-aged or older-aged individuals, although AIx only increased significantly in the YG. Thus, the transient changes in arterial stiffness in response to an acute moderate-intensity resistance exercise session may not be significant in middle-aged and older-aged adults. Performing resistance training at moderate intensity may be a viable option for middle-aged and older adults to improve muscle mass and function without producing large changes in arterial stiffness.

Future Research Directions

Future studies should examine how intensity plays a role in the arterial response to a resistance training session. In addition, studies examining how exercise volume affects the acute responses to resistance training at varying intensities are needed to help explain differences found in chronic studies. Also, more studies are needed to determine the mechanisms explaining how the arterial system responds to resistance training.

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Appendix A: IRB Approval Letter, Consent Form and Research Privacy Form

The UNIVERSITY of OKLAHOMA

Institutional Review Board for the Protection of Human Subjects

Initial Submission – Board Approval

Date: February 11, 2013

To: Michael G Bemben, PHD

IRB#: 1896
Meeting Date: 01/14/2013
Approval Date: 02/05/2013
Expiration Date: 12/31/2013

Study Title: The influence of age on cardiovascular measures following an acute bout of resistance exercise

Reference Number: 421099 **Study Status:** Active – Open **Collection/Use of PHI:** Yes

At its regularly scheduled meeting the IRB reviewed the above-referenced research study. Study documents (e.g. protocol, consent, survey, etc.) associated with this submission are listed on page 2 of this letter. To review and/or access the submission forms (e.g. application) as well as the study documents approved for this submission, open this study from the *My Studies* option, go to *Submission History*, go to *Completed Submissions* tab and then click the *Details* icon.

If this study required routing through the Office of Research Administration (ORA), you may *not begin your study yet*, as per OUHSC Institutional policy, until the contract through ORA is finalized and signed.

As principal investigator of this research study, it is your responsibility to:

- Conduct the research study in a manner consistent with the requirements of the IRB and federal regulations at 45 CFR 46 and/or 21 CFR 50 and 56.
- Obtain informed consent and research privacy authorization using the currently approved, stamped forms and retain all original, signed forms, if applicable.
- Request approval from the IRB prior to implementing any/all modifications.
- Promptly report to the IRB any harm experienced by a participant that is both unanticipated and related per IRB Policy.
- Maintain accurate and complete study records for evaluation by the HRPP quality improvement program and if applicable, inspection by regulatory agencies and/or the study sponsor.
- Promptly submit continuing review documents to the IRB upon notification approximately 60 days prior to the expiration date indicated above.

If you have questions about this notification or using iRIS, contact the IRB @ 405-271-2045 or irb@ouhsc.edu.

Sincerely,

Karen Beckman, MD
Chairperson, Institutional Review Board

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Initial Submission – Board Approval [cont'd.]

Study documents associated with this submission:

Study Document			
Title	Version Number	Version Date	Outcome
email recruitment language	Version 1.0	01/30/2013	Approved
Protocol	Version 1.0	12/17/2012	Approved
Pre Screening Subjects Recruitment Form	Version 1.0	12/17/2012	Approved
medical clearance form	Version 1.0	12/17/2012	Approved
Health Status Questionnaire	Version 1.0	12/17/2012	Approved
PARQ	Version 1.0	12/17/2012	Approved
Recruitment Flyer 2	Version 1.0	12/17/2012	Approved
Recruitment Flyer 1	Version 1.0	12/17/2012	Approved
HIPAA form 1-OUHSC	Version 1.1	01/18/2013	Approved

Study Consent Form			
Title	Version Number	Version Date	Outcome
consent	Version 1.5	12/17/2012	Approved

Information for Industry Sponsors: the columns titled Version Number and Version Date are specific to the electronic submission system (iRIS) and should not to be confused with information included in the Document and/or Consent title(s).

The UNIVERSITY of OKLAHOMA

Institutional Review Board for the Protection of Human Subjects

Modification/Notification – Board Approval

Date: March 14, 2013

IRB#: 1896
Meeting Date: 03/11/2013
Approval Date: 03/11/2013

To: Michael G Bemben, PHD

Study Title: The influence of age on cardiovascular measures following an acute bout of resistance exercise
Reference Number: 468519
Modification/Notification Summary:

> The number of visits will increase from 3-4 visits. To decrease the amount of time during the first visit, this session will be separated into 2 separate visits with the first visit only consisting of the consent process (consent forms, questionnaires, and screening). The second visit will be used to assess body composition, muscle thickness, and strength measurements (originally part of the approved first visit). Additionally, during the exercise session (visit 3 or 4) the rest periods between sets and exercises will be increased from 1 minute to 2-3 minutes. There will be no set cadence for each repetition but rather the subject will complete the exercises at their own rate of comfort. The PI will also include a warm-up for the first 2 exercises (leg press and chest press). The warm-up will consist of 8-10 repetitions at approximately 50% of their 1-RM. Addition of Michael E. Bibens as a sub-investigator for the study.

At its regularly scheduled meeting the IRB reviewed the above-referenced modification. Study documents (e.g. protocol, consent, survey, etc.) associated with this submission are listed on page 2 of this letter. To review and/or access the submission form (e.g. modification form) as well as the study documents approved for this submission, open this study from the *My Studies* option, go to *Submission History*, go to *Completed Submissions* tab and then click the *Details* icon.

If this modification includes revisions to the consent or privacy authorization forms, you are reminded to obtain informed consent and research privacy authorization using the currently approved, stamped forms and retain all original, signed forms, if applicable.

If you have questions about this notification or using iRIS, contact the HRPP office at (405) 271-2045 or irb@ouhsc.edu. The HRPP Administrator assigned for this submission: Karrie Meeks.

Sincerely,

Karen Beckman, MD
Chairperson, Institutional Review Board

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Modification/Notification – Board Approval [cont'd.]

Study documents associated with this submission:

Study Document			
Title	Version Number	Version Date	Outcome
email recruitment language	Version 1.2	02/20/2013	Approved
Protocol	Version 1.3	02/20/2013	Approved
medical clearance form	Version 1.3	02/20/2013	Approved
Recruitment Flyer 2	Version 1.3	02/20/2013	Approved
Recruitment Flyer 1	Version 1.3	02/20/2013	Approved

Study Consent Form			
Title	Version Number	Version Date	Outcome
consent	Version 1.8	02/20/2013	Approved

Information for Industry Sponsors: the columns titled Version Number and Version Date are specific to the electronic submission system (iRIS) and should not to be confused with information included in the Document and/or Consent title(s).

University of Oklahoma
Institutional Review Board
Informed Consent to Participate in a Research Study

Project Title: The Influence of Age on Cardiovascular Measures Following an Acute Bout of Resistance Exercise
Principal Investigator: Michael G. Bemben, PhD
Department: Health and Exercise Science

There is no benefit in participating in this research project. This includes any effect on your grades in any classes.
This is a research study. Research studies involve only individuals who choose to participate. Please take your time to make your decision. Discuss this with your family and friends.

Purpose of the Research Study

The purpose of this study is to determine how age affects different cardiovascular measurements after a session of weight lifting. Furthermore, we would like to examine how muscle mass plays a role in this response.

Number of Participants

About 100 men between the ages of 18-75 years will take part in this study, all at the University of Oklahoma.

Procedures

If you agree to be in this study, you will be asked to do the following:

1. **Forms/questionnaires**
   Informed consent will be obtained prior to completion of all questionnaires and any testing. You will be asked to complete a Health Status Questionnaire, protected health information authorization release form, and Physical activity readiness questionnaire (PAR-Q). (~30 minutes) If you are 45 years or older, you will also be asked to have your personal physician fill out a Medical Clearance Form indicating that you can participate in an exercise session. You may be required to pay your Physician to complete the Medical Clearance Form. If you meet the criteria from the completed questionnaires and medical exam, you will be able to participate in this study and we will ask you to complete three visits which include all of the procedures listed below. If there are reasons you cannot participate, you will be excluded from the study.

2. **Blood pressure**
   We will measure your blood pressure in the arm the same way that it is typically measured at a doctor's office. A cuff will be placed around the upper arm, it will inflate quickly, and then deflate slowly. Blood pressure will be taken twice and the value will be averaged. This will be performed at visit 1 and at the beginning and end of visits 3 and 4. (~5 minutes)

3. **Ankle-brachial index**

You will lie on your back for 10 minutes. A blood pressure cuff will be placed on your left arm and blood flow through your arm will be determined by a small probe with some gel. We will inflate a blood pressure cuff on your arm and then slowly deflate it as the probe remains on your arm. This measurement will be repeated on the right arm. Next, a blood pressure cuff will be placed around your left ankle and inflated. Blood flow through your leg will be determined in the same manner as your arms. We will repeat this on your right leg. The inflation of the cuff on each limb may cause some temporary discomfort. This will be completed during the visit 1. (~10 minutes).

4. **Standing height and weight**
   We will measure your body weight and height using a wall stadiometer and a digital scale. This will be completed at visit 1and 2. (~2 minutes)

5. **Muscle Thickness**
   We will measure your muscle thickness with an ultrasound machine. This procedure is similar to what is done to look at a baby in a women's uterus. A small amount of gel will be placed on a probe and this probe will be positioned on four different sites on the body. When an appropriate image is obtained, we will print this image from the ultrasound machine and, later, we will be able to analyze this image to determine muscle thickness. The muscle thickness in the arms and legs will be assessed.. This will be done at visits 2 and 3. (~10 minutes).

6. **Muscle Mass and Bone Mineral Density**
   You will have your total and regional muscle mass and bone mineral density determined by a bone scan machine called Dual Energy X-Ray Absorptiometry (DXA; GE Lunar Prodigy) in the Bone Density Laboratory by a trained DXA technician under the supervision of Dr. Debra Bemben. This procedure will tell us the amount of fat and muscle that you have in your body. During the scan you will be asked to lie still on your back on a table. This scan will take about 10 minutes. To determine your hydration status a sample of urine will also be taken. One bone scan will be required and performed at visit 2.

7. **Familiarization with exercises**
   You will be familiarized with the exercises during the first visit. (~10 minutes.)

8. **One-repetition maximum**
   We will assess your muscular strength on five machine exercises (Leg press, chest press, knee flexion, arm pull-down, and knee extension). We will assess this by one-repetition maximum (1-RM; the heaviest weight you can lift one time with good form) tests during the first visit. You will be supervised by trained personnel during all strength testing. This will be performed at visit 2. (~25 minutes)

9. **Central pressure**
   We will measure your blood pressure and at the same time we will place a small pen-like probe on your wrist which gives us information about the stiffness of your arteries and what the blood pressure is at your heart. This will be taken at the beginning and end of visits 3 and 4 for a total of 4 times. (~5 minutes)

10. **Pulse wave velocity**

We will measure the health of your arteries using a small, pen-shaped device.. We will find the pulse at the neck, thigh, and wrist. We will use a measuring tape to measure the distances between these pulses. We will place three sticky electrodes on your chest and will connect wires that are attached to a recorder. We will then place the pen-shaped device over the various pulses to measure "pulse waves". Placing the device over these pulses provides the machine with information about the time it takes the pulse to travel through the blood vessels. These times, combined with the measured distances, allows the machine to calculate the speed with which the "pulse wave" travels through the arteries. This speed provides us with useful information about arterial health. This will be taken at the beginning and end of visits 3 and 4 for a total of 4 times. (~15 minutes)

11. Heart measurements

We will measure the functional ability of your heart. A small ultrasound probe with gel on the end, as described in the muscle thickness section, will be placed on your chest over your heart as you lie down on a medical table. This will be taken at the beginning and end of visits 3 and 4 for a total of 4 times. (~10 minutes)

12. Forearm blood flow

We will measure the amount of blood flow in the smaller blood vessels of your forearm. We will prop up your wrist on a foam pad. We will measure the circumference of your forearm at its largest point. We will place two blood pressure cuffs over the arm: one around the wrist and one just above the elbow. We will place a mercury-filled strain gauge (similar in appearance and stretchiness to a rubber band) around the forearm. We will inflate the cuff at your wrist for one minute. We will then inflate and deflate the cuff just above the elbow to a low pressure six times. Each inflation will last ~7s and each deflation will last approximately ~8s. The cuff around the wrist stays inflated during this low pressure inflation and deflation of the cuff just above the elbow. This inflation and deflation takes a total time of ~90s leading to a total wrist cuff inflation time of ~2.5 minutes. The amount the strain gauge stretches is sensed by our machine and tells us the extent of the forearm blood flow. During this procedure, both cuffs will be inflated at the same time for a total of 42s (7 seconds x 6 inflations); regular deflations of the cuff above the elbow occur during this time and the pressure of this cuff is very low even when inflated. This will be taken at the beginning and end of visits 3 and 4 for a total of 4 times. (~10 minutes)

13. Exercise or resting visits

You will be randomly assigned to either an exercise or resting condition during visit 3. Randomization means that you are put in a group by chance. If you have an equal; 50/50 chance use the following comparison, like the flip of a coin. If there is a 1 in 4; 2 in 3 chance of receiving active study drug use the comparison of rolling a dice. A computer program at the study sponsor will make this random assignment. Neither you nor your physician will choose which group you will be in. During visit 4 you will be assigned to the other condition. Prior to visits 3 and 4 we ask that you not have any food or drink for 3 hours prior to the visits and that you do not consume any caffeine or alcohol 12 hours prior to testing. Furthermore, we ask that you do not exercise 24 hours prior to the visits. The exercise condition will consist of taking the previous measurements prior to exercise. After the measurements, you will perform 5 different exercises (leg press, chest press, knee flexion, arm pull-down, knee extension) at 65% 1RM actions (~25 minutes to finish exercises). You will rest ~2-3 minutes between sets and ~2-3 minutes between exercises. After exercise you will lie down for ~5 minutes and the same measurements taken pre-exercise will be performed. During the resting condition, the same procedure will be followed except that instead of exercising you will sit in a chair for ~25 minutes.

Length of Participation

There will be 4 visits to the laboratory for data collection. The first 2 visits will last approximately 40-60 minutes. The last 2 visits will last between approximately 1 ½ to 2 hours. A total time commitment will be approximately 4 ½ to 6 hours. Visits 2, 3 and 4 will be separated by a minimum of at least 3 days.

Risks of being in the study are

This research study involves exposure to radiation from one DXA scan, which is a type of xray procedure. This radiation is not necessary for medical care and is for research purposes only. You will receive radiation exposure of less than 2 mrem from each scan and a total dose of 2 mrem, which is less than the radiation received in 2.2 days from natural background radiation (~ 300 mrem/yr), such as naturally occurring radioactivity in soil. Any risk from this amount of radiation is too small to measure directly, and is small when compared to every day risks. Although the amount of radiation the subject will receive in this study is minimal, it is important for you to be aware that the risk from radiation exposure is cumulative over the life time.

There is always a risk of injury with any exercise program. All attempts will be made to minimize your risk of injury. Temporary muscle soreness will likely occur following strength testing and the exercise session. This soreness should be reduced within 24-48 hours following the exercise session or strength testing. Other possible risks may include feeling faint, fatigued, lightheaded and the possibility of passing out due to physical exertion.

Benefits of being in the study are

None.

Compensation

You will not be paid for your time and participation in this study.

Injury

In case of injury or illness resulting from this study, emergency medical treatment is available. However, you or your insurance company will be expected to pay the usual charge from this treatment. The University of Oklahoma Norman Campus has set aside no funds to compensate you in the event of injury.

Confidentiality

In published reports, there will be no information included that will make it possible to identify you. Research records will be stored securely for 2 years and only approved researchers will have access to the records. You will be asked to sign a separate authorization form for use or sharing of your protected health information.

There are organizations that may inspect and/or copy your research records for quality assurance and data analysis. These organizations include the OU Institutional Review Board.

701-A-1

Voluntary Nature of the Study

Participation in this study is voluntary. If you withdraw or decline participation, you will not be penalized or lose benefits or services unrelated to the study. If you decide to participate, you may decline to answer any question and may choose to withdraw at any time.

You have the right to access the research data that has been collected about you as a part of this research study. However, you may not have access to this information until the entire research study has completely finished and you consent to this temporary restriction.

Contacts and Questions

If you have concerns or complaints about the research, the researcher(s) conducting this study can be contacted at 325-5211 or via email: mgbemben@ou.edu for Michael Bemben, Robert.S.Thiebaud-1@ou.edu for Robert Thiebaud.

Contact the researcher(s) if you have questions, or if you have experienced a research-related injury.

If you cannot reach the Investigator or wish to speak to someone other than the investigator, contact the OUHSC Director, Office of Human Research Participant Protection at 405-271-2045.

For questions about your rights as a research participant, contact the OUHSC Director, Office of Human Research Participant Protection at 405-271-2045.

You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

Signature:

By signing this form, you are agreeing to participate in this research study under the conditions described. You have not given up any of your legal rights or released any individual or entity from liability for negligence. You have been given an opportunity to ask questions. You will be given a copy of this consent document.

I agree to participate in this study:

PARTICIPANT SIGNATURE (age >18) (Or Legally Authorized Representative)	Printed Name	Date
SIGNATURE OF PERSON OBTAINING CONSENT	Printed Name	Date

IRB NUMBER: 1896
IRB APPROVAL DATE: 03/11/2013
IRB EXPIRATION DATE: 12/31/2013

IRB No.: 1896

AUTHORIZATION TO USE or DISCLOSE
PROTECTED HEALTH INFORMATION FOR RESEARCH
An Informed Consent Document for Research Participation may also be required.
Form 2 must be used for research involving psychotherapy notes.

Title of Research Project: **The influence of age on cardiovsacular measures following an acute bout of resistance exercise.**

Leader of Research Team: **Michael G. Bemben**

Address: **Huston Hufman Center 115, Norman, OK 73019**

Phone Number**: 405-325-2717**

If you decide to join this research project, University of Oklahoma Health Sciences Center (OUHSC) researchers may use or share (disclose) information about you that is considered to be protected health information for their research. Protected health information is information about past, present, and future medical treatment or condition that is identifiable to you. It will be called PHI in this Authorization.

PHI To Be Used or Shared. Federal law requires that researchers get your permission (authorization) to use or share your PHI. If you give permission, the researchers may use or share with the people identified in this Authorization any PHI related to this research from your medical records and from any test results. Information used or shared may include all information relating to any tests, procedures, surveys, or interviews as outlined in the consent form; medical records and charts; name, address, telephone number, date of birth, race, and government-issued identification numbers.

Purposes for Using or Sharing PHI. If you give permission, the researchers may use your PHI to assess the effect of resistance exercise on cardiovascular parameters across different ages.

Other Use and Sharing of PHI. If you give permission, the researchers may also use your PHI to develop new procedures or commercial products. They may share your PHI with other researchers, the research sponsor, and its agents, the OUHSC Institutional Review Board, auditors and inspectors who check the research, and government agencies such as the Food and Drug Administration (FDA) and the Department of Health and Human Services (HHS). The researchers may also share your PHI with all researchers collaborating on this project.

Confidentiality. Although the researchers may report their findings in scientific journals or meetings, they will not identify you in their reports. The researchers will try to keep your information confidential, but confidentiality is not guaranteed. The law does not require everyone receiving the information based on this authorization to keep it confidential, so they could release it to others, and federal law may no longer protect it.

YOU UNDERSTAND THAT YOUR PROTECTED HEALTH INFORMATION MAY INCLUDE INFORMATION REGARDING A COMMUNICABLE OR NONCOMMUNICABLE DISEASE.

Voluntary Choice. The choice to give OUHSC researchers permission to use or share your PHI for their research is voluntary. It is completely up to you. No one can force you to give permission. However, you must give permission for OUHSC researchers to use or share your PHI if you want to participate in the research and, if you cancel your authorization, you can no longer participate in this study.

Refusing to give permission will not affect your ability to get routine treatment or health care from OUHSC.

Cancelling Permission. If you give the OUHSC researchers permission to use or share your PHI, you have a right to cancel your permission whenever you want. However, cancelling your permission will not apply to information that the researchers have already used, relied on, or shared.

End of Permission. Unless you cancel it, permission for OUHSC researchers to use or share your PHI for their research will never end. You may cancel your permission at any time by writing to:

Privacy Official University of Oklahoma Health Sciences Center PO Box 26901 Oklahoma City, OK 73190	or	Privacy Board University of Oklahoma Health Sciences Center PO Box 26901 Oklahoma City, OK 73190

If you have questions, call: (405) 271-2511 or (405 271-2045.

Access to Information. You have the right to access the medical information that has been collected about you as a part of this research study. However, you may not have access to this medical information until the entire research study is completely finished. You consent to this temporary restriction.

Giving Permission. By signing this form, you give OUHSC and OUHSC's researchers led by Michael G. Bemben, permission to share your PHI for the research project called The influence of age on cardiovascular measures following an acute bout of resistance exercise.

Patient/Participant Name: ______________________

_____________________________________ _____________
Signature of Patient-Participant Date
or Parent if Participant is a minor

Or

_____________________________________ _____________

IRB Office Use Only
Version 01/04/12

Signature of Legal Representative** Date

**If signed by a Legal Representative of the Patient-Participant, provide a description of the relationship to the Patient-Participant and the Authority to Act as Legal Representative:

____

OUHSC may ask you to produce evidence of your relationship.

A signed copy of this form must be given to the Patient-Participant or the Legal Representative at the time this signed form is provided to the researcher or his representative.

IRB No.: 1896

Appendix B: Pre-Screening Form, Medical Clearance, PAR-Q and Health History Questionnaire

Pre-Screening Subjects Recruitment Form

University of Oklahoma Neuromuscular Laboratory

"The influence of age on cardiovascular measures after an acute bout of resistance exercise"

NAME: ______________________ PHONE NUMBER: ________________

Inclusion Criteria- The inclusion criteria for this study requires that each subject:

☐ Is a male aged 18-75 years

☐ Is recreationally active

☐ Has no known orthopedic disorders which would prevent participation in the exercise session

☐ Is under the DXA weight limit (300lbs)

☐ Is free from pulmonary, cardiovascular, or metabolic diseases (asthma, diabetes, heart, uncontrolled hypertension or COPD)

☐ Is not hypertensive (SBP >140 and/or DBP >90) – this can be either naturally or under control with medication

Exclusion Criteria-The exclusion criteria for this study require that each subject:

☐ Is outside the age range of 18-75 years

☐ Has a BMI ≥ 30 kg/m^2

☐ Is highly resistance trained (in a resistance training program lifting ≥ 3 times per week within the precious 6 months or competitively lifted during the previous 2 years)

☐ Is highly endurance trained (perform vigorous endurance exercise ≥ 5 times per week within the previous 6 months or competitively raced during the previous 2 years)

☐ Has known orthopedic disorders which would prevent participation in the exercise program

☐ Is over the DXA weight limit (300lbs)

☐ Is hypertensive (SBP >140 and/or DBP >90) – this can be either naturally or under control with medication

☐ Is taking anabolic steroids

☐ Is a smoker

NOTES: ____

IRB APPROVED

IRB NUMBER: 1896
IRB APPROVAL DATE: 02/05/2013

Subject Medical Clearance Form

University of Oklahoma Neuromuscular Laboratory

To the Attending Physician of: ____

The above-named individual has indicated that he wishes to participate in a research study investigating the effect of age on cardiovascular measures following an acute bout of resistance exercise in men aged 18-75. Prior to participation, subjects that are 45-75 years of age are required to obtain medical clearance from their personal physician(s).

This study requires testing sessions that involve one whole body DXA scan, ultrasound muscle thickness assessments, blood pressure assessment, forearm blood flow assessment as measured by strain-gauge plethysmography (non-invasive), pulse wave velocity assessment as measured by applanation tonometry (non-invasive), strength assessment using standard American College of Sports Medicine one-repetition maximum procedures, heart function assessment as measured by echocardiography and a health history questionnaire.

Participants in this study will exercise one time and perform 3 sets of 10 reps for 5 exercises at 70% of their one-repetition maximum. The strength training will be performed on standard exercise machines. The following exercises will be performed: chest press, lat pull-down, leg press, leg extension, and leg curl.

Specific inclusion and exclusion criteria apply to the subjects recruited for this study. Below are the exclusion criteria. Please check any boxes that apply to the above-named individual.

☐ Uncontrolled hypertension
☐ Weight over 300lbs
☐ BMI$\geq$30kg/m^2
☐ Orthopedic disability or injury that would prevent her from performing weight-machine resistance exercises
☐ Metabolic, heart, or pulmonary disorder that would prevent her from participation in the program
☐ Peripheral vascular disease
☐ Taking anabolic steroids
☐ Smoker

☐ Other: ____________

☐ I recommend that the above-named individual be allowed to participate in the study.
☐ I **do not** recommend that the above-named individual be allowed to participate in the study.

MEDICATIONS/NOTES: ____

____

Physician Name: ______________________ Contact Number: ______________
(please print)
Physician Signature: ______________________ Date: ______________

This study has been approved by the University of Oklahoma Institutional Review Board. *For questions, please contact Michael G. Bemben, Ph.D. at mgbemben@ou.edu.*

IRB NUMBER: 1896
IRB APPROVAL DATE: 02/05/2013

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ________________________________

SIGNATURE ________________________________ DATE ________________________________

SIGNATURE OF PARENT ________________________________ WITNESS ________________________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

IRB NUMBER: 1896
IRB APPROVAL DATE: 02/05/2013

Supported by: Health Canada Santé Canada

continued on other side...

Neuromuscular Research Laboratory

OU Department of Health and Exercise Science

Health Status Questionnaire

Instructions Complete each question accurately. All information provided is confidential.

Part 1. Information about the individual

1.____
Date

2. ____
Legal name   Nickname

3.____
Mailing address

____
Home phone   Business phone

4.Gender (circle one): Female Male

5. Year of birth: ___________________________ Age __________

6. Number of hours worked per week: Less than 20 20-40 41-60 Over 60

More than 25% of time spent on job (circle all that apply)

Sitting at desk Lifting or carrying loads Standing Walking Driving

Part 2. Medical history

7. Circle any who died of heart attack before age 50:

Father Mother Brother Sister Grandparent

8.Date of: Last medical physical exam: _______________Last physical fitness test: _________________
Year   Year

9. Circle operations you have had:

Back	Heart	Kidney	Eyes	Joint	Neck
Ears	Hernia	Lung	Other ______________		

10. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

Alcoholism	Diabetes	Kidney problem
Anemia, sickle cell	Emphysema	Mental illness
Anemia, other	Epilepsy	Neck strain
Asthma	Eye problems	Obesity
Back strain	Gout	Osteoporosis
Bleeding trait	Hearing loss	Phlebitis
Bronchitis, chronic	Heart problems	Rheumatoid arthritis
Cancer	High blood pressure	Stroke
Cirrhosis, liver	Hypoglycemia	Thyroid problem
Concussion	Hyperlipidemia	Ulcer
Congenital defect	Infectious mononucleosis	Other ______________

11. Circle all medicine taken in last 6 months:

Blood thinner	Epilepsy medication	Nitroglycerin
Diabetic pill	Heart-rhythm medication	Estrogen
Digitalis	High-blood-pressure medication	Thyroid
Diuretic	Insulin	Corticosteroids
Asthma	Other ______________	

12. Any of these health symptoms that occurs frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:

1 = Practically never   2 = Infrequently   3 = Sometimes   4 = Fairly often   5 = Very often

a. Cough up blood 1 2 3 4 5	d. Leg pain 1 2 3 4 5	g. Swollen joints 1 2 3 4 5
b. Abdominal pain 1 2 3 4 5	e. Arm or shoulder pain 1 2 3 4 5	h. Feel faint 1 2 3 4 5
c. Low back pain 1 2 3 4 5	f. Chest pain 1 2 3 4 5	I. Dizziness 1 2 3 4 5
j. Breathless with slight exertion 1 2 3 4 5		

13. Do any of the following apply:

- A sudden death in your biological father or brother, or mother or sister prior to age 55 or 65, respectively? Yes No
- Current smoker or have you quit smoking within the past 6 months? Yes No
- Do you take hypertensive medication or have a confirmed systolic or diastolic blood pressure $\geq$140 or 90 mmHg, respectively? Yes No
- Take lipid lowering medication or have high blood cholesterol? Yes No
- You have a confirmed fasting blood glucose of $\geq$100 mg/dL? Yes No
- Have you recently been diagnosed as clinically obese (BMI > 30)? Yes No
- Are you sedentary? Yes No
- Diagnosed Crohn's or Inflammatory Bowel Disease Yes No
- Past fracture of a hip, pelvis, or femur Yes No
- Major Surgery within the last 6 months Yes No
- Been diagnosed with varicose veins Yes No
- Family history of Deep Vein Thrombosis or Pulmonary Embolism Yes No

Part 3. Health-related behavior

14. Do you now smoke or chew tobacco? Yes No

15. If you are a smoker, indicate number smoked per day:

Cigarettes: 40 or more 20-39 10-19 1-9

Cigars or pipes only: 5 or more or any inhaled Less than 5, none inhaled

16. Weight now: ________lb. One year ago: ________lb.. Age 21: ________lb.

17. Thinking about the things you do at work, how would you rate yourself as to the amount of physical activity you get compared with others of your age and sex?

1. Much more active
2. Somewhat more active
3. About the same
4. Somewhat less active
5. Much less active
6. Not applicable

18. Now, thinking about the things you do outside of work, how would you rate yourself as to the amount of physical activity you get compared with others of your age and sex?

1. Much more active
2. Somewhat more active
3. About the same
4. Somewhat less active
5. Much less active
6. Not applicable

19. Do you regularly engage in aerobic (such as running, walking, biking, swimming) exercise?

1. Yes 2. No

20. If you answered "yes" to question #19, how frequently (hours and days per week) have you engaged in aerobic activities during the past 6 months? Is your intensity low, moderate or vigorous?

____

21. Do you regularly engage in strength-training exercise program such as lifting weights, using weight-machines or elastic bands?

1. Yes 2. No

22. If you answered "yes" to question #21, how frequently (times per week) have you engaged in strength-training exercise during the past 6 months?

____

Appendix C: Sample Data Collection Forms

Subject ID________
DATE: _______ TIME: ________

Visit 1 Flow List

- ☐ Forms (~30 minutes)
  - ☐ Exclusion Criteria
  - ☐ Consent Form
  - ☐ HIPAA Form
  - ☐ PAR-Q
  - ☐ HSQ
  - ☐ Birth date __________ if younger than 18 yrs or older than 75 yrs exclude
- ☐ Patient lie on table for 5 minutes (~15 minutes)
  - ☐ Blood pressure: 1)________mmHg, 2)_________mmHg
  - ☐ Make sure less than 5 mmHg different
  - ☐ Measure ankle brachial index (ankle/brachial: if <0.9 exclude) Ankle will be higher than arm.
    - ▪ right arm ________
    - ▪ right leg _______ (Right ABI:______)
    - ▪ left leg _______
    - ▪ left arm _______ (Left ABI:______)
- ☐ Height (cm)_______
- ☐ Weight (kg)_______
  - ☐ BMI (kg/m2) ________
- ☐ **Familiarization with machine exercises and 1-RM**
  - ☐ Start with light weight. Do 8-10 reps. Rest 1 minute.
  - ☐ Increase weight slightly
  - ☐ Perform 5 reps.
  - ☐ Move to next exercise
  - ☐ Order of exercises (Leg press, chest press, leg flexion, lat pulldown, leg extension)
  - ☐ Write seat adjustments for exercise on Visit 2 sheet.
- ☐ Schedule next visits
  - ☐ Reminders for visit 2
  - ☐ Wear shorts and a t-shirt that you can exercise in and that doesn't have any plastic, metal, or reflection material

- Do not exercise 24 hours prior to coming
- Well hydrated.

Visit 2 ID#:_______

Date: ______; Time______

- Calibrate DEXA and Spectrometer
  - DEXA: use phantom
  - Spectrometer: use deionized water with value reading 1.000.
- Urine Sample/Urine Specific Gravity________
  - If more than 1.029, drink some water and wait 30 minutes to test again
  - If less than 1.004, reschedule because too hydrated
  - Record on sheet
- Put in ID in ultrasound machine
  - Patient ID: RD (#)
  - Patient Name: Visit 2 MTH
- **Muscle Thickness (~15 minutes) Ask participant to keep marks. Freq set at 6.0, F5 set at 40. Adjust gain if needed.**
  - Arms: 60% between acromion process and lateral epicondyle of humerus.
    - Total Distance______ cm, 60% distance________
  - Legs: 50% between greater trochanter and lateral epicondyle of femur. Rectus Femoris should be in middle of picture for ant.
    - Total Distance_______ cm, 50% distance ________
  - Anterior Leg_____, _______
  - Posterior Leg_____, _______
  - Anterior Arm______, _______
  - Posterior Arm______, _______
- **DEXA Scan (~15 minutes)**
  - Weight______.
  - Enter subject information in DXA lab book and computer.
  - Enter in first name: Dissertation,
  - Enter in last name: Rob,
  - Enter ID: RD_ _.
  - Enter height____, weight____, birthdate____, gender, race
  - Prepare subject for DXA scan
    - Remove any jewelry, plastic, metal rings etc. that might affect scan. Remove shoes. Should have shorts and t-shirt.

- Explain safety features

- Line up subject straight on scanner
- Explain what will happen during scan and to relax and not move.
- Move scanner back to home position. Ctrl H.
- Analyze Scan-ROI, Save Scan
- Check bone density
  - If t-score less than -1.5 talk to Dr. Deb.
- Print off

- **Perform 1-RM tests** (Make sure good form, don't overestimate 1RM because of bad form)
  - Estimate 50% perform 8-10 times, rest 1 minute
  - Increase weight, perform 3-5 times, then rest ~ 1-2 minutes
  - Perform 1 RM estimate.
  - Keep gradually increasing the weight until, 1-RM is reached

Exercise	**Weight of 50% estimated**	**Trials**					**# of machine positions**
		1	**2**	**3**	**4**	**5**	
Leg Press							**#:**
Chest Press							**Seat:** **Arm:**
Leg Flexion							**Back:** **Leg:**
Lat Pulldown							**#:**
Leg Extension							**Back:** **Leg:**

Reminders for visit 3:

Wear shorts/t-shirt

No exercise 24 hours prior to testing

No alcohol or caffeine 12 hours prior to testing

No eating 3 hours prior to testing

Visit 3 ID#:________

Date: ___________ Time: ___________ Temperature: __________

Exercise Visit __________ Control Visit ___________

Pre-exercise Measurements (~30-40 minutes)

- ☐ Turn on sphygmacor computer, Hokanson computer:
  - ☐ Sphygmacor: **stiffness**
    - ☐ Turn on sphygmacor and then computer
    - ☐ Enter subject information
      1. Last Name: Dissertation
      2. First Name: Rob
      3. ID: RD_ _
      4. Birthdate:
  - ☐ Hokanson: **blood**
    - ☐ Turn on from bottom to top (wait until after PWV measurements)
    - ☐ Enter subject information
      1. Last Name: Dissertation
      2. First Name Rob
      3. ID: 100-00-00_ _.
      4. Birthdate:
- ☐ Place muscle thickness probe on ultrasound machine
- ☐ Put in ID in ultrasound machine
  - ☐ Patient ID: RD (#)
  - ☐ Patient Name: Visit 3 MTH
- ☐ **Muscle Thickness (~15 minutes) Ask participant to keep marks. Freq set at 6.0, F5 set at 40. Adjust gain if needed.**
  - ☐ Arms: 60% between acromion process and lateral epicondyle of humerus.
    - ☐ 60% distance_________
  - ☐ Legs: 50% between greater trochanter and lateral epicondyle of femur. Rectus Femoris should be in middle of picture for ant. Bone hard to see on back of leg.
    - ☐ 50% distance_________
  - ☐ Anterior Leg_____, ________
  - ☐ Posterior Leg_____, ________
  - ☐ Anterior Arm______, ________

- Posterior Arm______, ______
- Participant lies on table for ~10 minutes
  - Measure distance from **carotid pulse to sternal notch**
    - Distance: ___________
  - Measure distance from **sternal notch to radial pulse**
    - Distance: ___________
    - **Sternal-radial minus carotid-sternal = ___________ (Carotid-Radial distance)**
  - Measure distance from **sternal notch to femoral pulse**
    - Distance: ___________
    - **Sternal-femoral minus carotid-sternal = __________ (Carotid-Femoral distance)**
  - Measure distance from **around largest part of forearm**
    - Distance from radial tuberosity: ___________
    - Circumference: _______, Circumference-2=__________
  - Clean hair from chest, wipe with alcohol, let dry, and place **electrodes**
  - Change ultrasound probe to heart probe
- Take blood pressure at ~7-8 minutes on right arm (take three if needed). <5 mmHg apart
  - BP1:____/_____mmHg, BP2:____/____mmHg
  - Avg.: ______/______ mmHg
- **Cardiovascular measurements (Tilt chin up / 45 degrees for carotid measurements)**
  - Echocardiography: Find heart on back. Subject lie on side after PWV.
  - Pulse wave analysis
    - **Put in blood pressure, put in visit 3 pre-_____(condition)**
    - Make sure all variables are green.
  - Pulse wave velocity
    - **Put in blood pressure, put in visit 3 pre-_____(condition)**
    - Put distance for carotid-**radial** in computer: _________
    - **Put in blood pressure**
    - Put distance for carotid-**femoral** in computer: ________
- **Forearm blood flow**
  - Place one pad under shoulder
  - Place two pads in shape of square and with wrist holder pad on top at the area of the wrist
  - Place sc-10 cuff with pressure inflator on wrist

- ☐ Place sc-12 cuff over arm
- ☐ Place string gauge over forearm where mark is
  - ☐ String gauge size____________
- ☐ Inflate wrist cuff to 200 mmHg for 1 minute
- ☐ After 1 minute start computer. Take 6 readings.

☐ **Exercise or Control Session**

- ☐ If control rest for ~25 minutes and proceed to post measurements
- ☐ **If exercise, 2-3 minutes rest between sets and exercises**
- ☐ **10 reps each exercise: lower weight if they can't get 10. Goal is 10.**
- ☐ **Warm up 1 set 8-10 reps at ~50% 1RM for Leg Press/Chest Press**
- ☐ Leg Press plates______: Machine setting:______
  - ☐ Set 1 reps______; Set 2 reps______; Set 3 reps______
- ☐ Chest Press plates______: Arm_____; Seat______
  - ☐ Set 1 reps______; Set 2 reps______; Set 3 reps______
- ☐ Knee Flexion plates______: Leg_____; Back_______
  - ☐ Set 1 reps______; Set 2 reps______; Set 3 reps______
- ☐ Lat Pulldown plates______: Seat_______
  - ☐ Set 1 reps______; Set 2 reps______; Set 3 reps______
- ☐ Knee Extension plates______: Leg______; Back______
  - ☐ Set 1 reps______; Set 2 reps______; Set 3 reps______

☐ **Post-exercise measurements**

- ☐ Participant lies on table
- ☐ Take blood pressure at 5 minutes: ____/____mmHg; ____/____mmHg:
- ☐ Avg: ____/____mmHg

☐ **Cardiovascular measurements (Put new blood pressure in sphygmacor)**

- ☐ Echocardiography: **Find heart on back. Lie on side after PWV measurements.**
- ☐ Pulse wave analysis: **Put in new BP. Make note that it is post measurements.**
- ☐ Pulse wave velocity: **Put in new BP. Make note that it is post measurements.**
  - ☐ Put distance for carotid-**radial** in computer: _________,
  - ☐ Put distance for carotid-**femoral** in computer: ________

☐ **Forearm blood flow**

- ☐ Place one pad under shoulder
- ☐ Place two pads in shape of square and with wrist holder pad on top at the area of the wrist

- Place sc-10 cuff with pressure inflator on wrist
- Place sc-12 cuff over arm
- Place string gauge over forearm where mark is
  - String gauge size____________
- Inflate wrist cuff to 200 mmHg for 1 minute
- After 1 minute start computer
- Take 6 readings and stop.

Pre	**Beat 1**	**Beat 2**	**Beat 3**	**Beat 4**	**Beat 5**
EDD (cm)					
EDV (ml)					
ESD (cm)					
ESV (ml)					
SV (ml)					
HR (bpm)					
CO (l/min)					
EF (%)					
FS (%)					

Post	**Beat 1**	**Beat 2**	**Beat 3**	**Beat 4**	**Beat5**

EDD (cm)					
EDV (ml)					
ESD (cm)					
ESV (ml)					
SV (ml)					
HR (bpm)					
CO (l/min)					
EF (%)					
FS (%)					

Pre: Forearm Blood Flow (%/min)
1
2
3
4
5

6
Post: Forearm Blood Flow (%/min)
1
2
3
4
5
6

Enter information into spreadsheet. FBF measured peak to peak for 3 s.

Additional Notes:

Visit 4 ID#:_________

Date: __________ Time: __________ Temperature: _________

Exercise Visit _________ Control Visit __________

Pre-exercise Measurements (~30-40 minutes)

- ☐ Turn on sphygmacor computer, Hokanson:
  - ☐ Sphygmacor: **stiffness**
    - ☐ Turn on sphygmacor and then computer
    - ☐ Choose subject ID___
  - ☐ Hokanson: **blood**
    - ☐ Turn on from bottom to top

- Choose subject ID___
- Participant lies on table for ~10 minutes
  - Forearm blood flow distance______. Place mark there.
    - String gauge size______.
  - Clean hair from chest, wipe with alcohol, let dry, and place **electrodes**
  - Change ultrasound probe to heart probe
- Take blood pressure at ~7-8 minutes on right arm (take three if needed)
  - BP1:____/____mmHg,BP2:____/____mmHg,
  - Avg.: ____/___ mmHg
- **Cardiovascular measurements (Tilt chin up / 45 degrees for carotid measurements)**
  - Echocardiography: Find heart on back. Subject lie on side after PWV.
  - Pulse wave analysis
    - **Put in blood pressure, put in visit 4 pre-_____(condition)**
    - Make sure all variables are green.
  - Pulse wave velocity
    - **Put in blood pressure, put in visit 4 pre-_____(condition)**
    - Put distance for carotid-**radial** in computer: _________
    - **Put in blood pressure**
    - Put distance for carotid-**femoral** in computer: ________
- **Forearm blood flow.**
  - Place one pad under shoulder
  - Place two pads in shape of square and with wrist holder pad on top at the area of the wrist
  - Place sc-10 cuff with pressure inflator on wrist
  - Place sc-12 cuff over arm
  - Place string gauge over forearm where mark is
  - Inflate wrist cuff to 200 mmHg for 1 minute
  - After 1 minute start computer
  - Take 6 readings and stop
- **Exercise or Control Session**
  - If control rest for ~25 minutes and proceed to post measurements
  - **If exercise, 2-3 minutes rest between sets and exercises**
  - **10 reps each exercise: lower weight if they can't get 10. Goal is 10.**
  - **Warm up 1 set 8-10 reps at ~50% 1RM for Leg Press/Chest Press**
  - Leg Press plates______: Machine setting:______
    - Set 1 reps______; Set 2 reps______; Set 3 reps______

- Chest Press plates______: Arm_____; Seat______
  - Set 1 reps______; Set 2 reps______; Set 3 reps______
- Knee Flexion plates______: Leg_____; Back_______
  - Set 1 reps______; Set 2 reps______; Set 3 reps______
- Lat Pulldown plates______: Seat_______
  - Set 1 reps______; Set 2 reps______; Set 3 reps______
- Knee Extension plates______: Leg______; Back______
  - Set 1 reps______; Set 2 reps______; Set 3 reps______

- **Post-exercise measurements**
  - Participant lies on table
  - Take blood pressure at 5 minutes: ____/____mmHg; ____/____mmHg:
  - Avg: ____/____mmHg
- **Cardiovascular measurements (Put new blood pressure in sphygmacor)**
  - Echocardiography: **Lie on side after PWV measurements.**
    - Make sure good image using circle technique
    - Save 2 images so that you **have 3 good heartbeats**
  - Pulse wave analysis: **Put in new BP. Make note that it is post measurements.**
  - Pulse wave velocity (Carotid-Femoral/Radial minus carotid-sternal distance)
    - Put distance for carotid-**radial** in computer: _________
    - Put distance for carotid-**femoral** in computer: ________
- **Forearm blood flow**
  - Place one pad under shoulder
  - Place two pads in shape of square and with wrist holder pad on top at the area of the wrist. Place sc-10 cuff with pressure inflator on wrist. Place sc-12 cuff over arm
  - Place string gauge over forearm where mark is
  - Inflate wrist cuff to 200 mmHg for 1 minute
  - After 1 minute start computer, take 6 readings, then stop

Pre	**Beat 1**	**Beat 2**	**Beat 3**	**Beat 4**
EDD (cm)				
EDV (ml)				
ESD (cm)				

ESV (ml)				
SV (ml)				
HR (bpm)				
CO (l/min)				
EF (%)				
FS (%)				

Post	**Beat 1**	**Beat 2**	**Beat 3**	**Beat 4**
EDD (cm)				
EDV (ml)				
ESD (cm)				
ESV (ml)				
SV (ml)				
HR (bpm)				
CO (l/min)				
EF (%)				
FS (%)				

Pre: Forearm Blood Flow Measurement	**Edited Value (%/min)**

1	
2	
3	
4	
5	
6	
Post: Forearm Blood Flow Measurement	**Edited Value (%/min)**
1	
2	
3	
4	
5	
6	

Enter information into spreadsheet. FBF measured peak to peak for 3 s.

Additional Notes:

Appendix D: Raw Data

Subject ID	Age (years)	Group	Leg Press 1-RM plates (1 plate = 20 lbs)	Leg Press 1-RM pounds	Leg Press 1-RM (kg)	Leg Press 65% 1RM (lb)
RD1	28.0	1	24 + 3 reps	446.0	202.7	312.0
RD2	65.9	3	14.5	289.6	131.6	188.2
RD3	27.7	1	15.5	309.6	140.7	201.0
RD4	60.0	3	15.5	309.6	140.7	201.0
RD5	22.5	1	14.0	280.0	127.3	182.0
RD6	32.8	1	17.5	349.6	158.9	227.2
RD7	72.3	3	17.0	340.0	154.6	221.0
RD8	75.6	3	10.0	200.0	90.9	130.0
RD9	43.2	2	15.0	300.0	136.4	195.0
RD10	74.9	3	12.0	240.0	109.1	156.0
RD11	26.8	1	14.5	289.6	131.6	188.2
RD12	22.5	1	16.5	329.6	149.8	214.2
RD13	71.2	3	13.5	269.6	122.6	175.2
RD14	46.0	2	14.5	289.6	131.6	188.2
RD15	27.2	1	18.5	369.6	168.0	240.2
RD16	49.8	2	16.0	320.0	145.5	208.0
RD17	61.2	3	15.5	309.6	140.7	201.0
RD18						
RD19						
RD20	47.3	2	11.0	220.0	100.0	143.0
RD21						
RD22	21.7	1	19.5	389.6	177.1	253.2
RD23	60.3	3	10.0	200.0	90.9	130.0
RD24	61.3	3	11.0	220.0	100.0	143.0
RD25						
RD26	56.1	2	15.0	300.0	136.4	195.0
RD27	53.5	2	12.5	249.6	113.5	162.2
RD28	46.8	2	17.0	340.0	154.6	221.0
RD29	27.0	1	15.0	300.0	136.4	195.0
RD30	29.0	1	19.0	380.0	172.7	247.0
RD31	29.8	1	19.5	389.6	177.1	253.2
RD32	27.2	1	13.5	269.6	122.6	175.2
RD33	57.2	2	16.5	329.6	149.8	214.2
RD34	48.8	2	15.5	309.6	140.7	201.0
RD35						
RD36	71.1	3	10.5	209.6	95.3	136.2
RD37	51.6	2	12.0	240.0	109.1	156.0
RD38	40.8	2	25.0	500.0	227.3	325.0
RD39	44.0	2	17.0	340.0	154.6	221.0
RD40	48.9	2	14.0	280.0	127.3	182.0
RD41	57.0	2	11.0	220.0	100.0	143.0
RD42			14.0	280.0	127.3	182.0
RD43	24.2	1	17.5	349.6	158.9	227.2

Warmup Weight (lbs)	Warmup Weight (kg)	Sets Weight Used (lbs)	Sets Weight Used (kg)	Total Volume (Weight (kg)xSetsxReps)
140.0	63.6	180.0	81.8	3090.9
149.6	68.0	209.6	95.3	3538.2
149.6	68.0	200.0	90.9	3407.3
140.0	63.6	180.0	81.8	3090.9
169.6	77.1	229.6	104.4	3901.8
169.6	77.1	220.0	100.0	3588.9
100.0	45.5	129.6	58.9	2221.8
149.6	68.0	189.6	86.2	3265.5
120.0	54.5	149.6	68.0	2585.5
140.0	63.6	189.6	86.2	3221.8
160.0	72.7	209.6	95.3	3585.5
129.6	58.9	169.6	77.1	2901.8
140.0	63.6	180.0	81.8	3090.9
180.0	81.8	240.0	109.1	4090.9
160.0	72.7	200.0	90.9	3454.5
149.6	68.0	200.0	90.9	3407.3
	0.0		0.0	0.0
	0.0		0.0	0.0
109.6	49.8	140.0	63.6	2407.3
	0.0		0.0	0.0
200.0	90.9	249.6	113.5	4312.7
100.0	45.5	129.6	58.9	2221.8
109.6	49.8	140.0	63.6	2407.3
	0.0		0.0	0.0
149.6	68.0	169.6	77.1	2992.7
120.0	54.5	160.0	72.7	2727.3
169.6	77.1	209.6	95.3	3629.1
149.6	68.0	189.6	86.2	3265.5
189.6	86.2	240.0	109.1	4134.5
189.6	86.2	249.6	113.5	4265.5
129.6	58.9	169.6	77.1	2901.8
160.0	72.7	209.6	95.3	3585.5
149.6	68.0	200.0	90.9	3407.3
	0.0		0.0	0.0
100.0	45.5	140.0	63.6	2363.6
120.0	54.5	149.6	68.0	2585.5
249.6	113.5	320.0	145.5	5498.2
169.6	77.1	220.0	100.0	3770.9
140.0	63.6	180.0	81.8	3090.9
110.0	50.0	140.0	63.6	2536.4
140.0	63.6		0.0	636.4
169.6	77.1	220.0	100.0	3770.9

Chest Press 1-RM (kg)	Chest Press 65% 1RM	Warmup Weight (kg)	Sets Weight Used (kg)	Total Volume (Weight (kg)xSetsxReps)
79.0	52.0			
45.5	30.7	20.2	27.2	1018.0
58.5	38.0	27.2	38.5	1427.0
47.0	30.6	20.2	31.5	1127.5
56.4	36.7	20.2	32.7	1183.0
67.5	43.9	31.5	45.0	1665.0
79.0	52.0	38.5	47.2	1801.0
45.0	29.3	20.2	27.2	1018.0
76.9	50.0	38.5	52.0	1945.0
52.0	33.8	25.0	31.5	1195.0
67.5	43.0	31.5	45.0	1665.0
93.0	60.5	45.0	58.5	2205.0
52.0	33.8	25.0	31.5	1195.0
65.5	42.6	31.5	40.7	1492.0
81.2	52.8	38.5	52.0	1945.0
100.0	65.0	47.2	65.5	2367.0
85.5	55.6	40.7	52.0	1967.0
				0.0
				0.0
60.7	39.5	31.5	38.5	1470.0
				0.0
106.0	68.9	52.0	67.7	2551.0
38.5	25.0	18.0	25.0	930.0
52.0	33.8	25.0	31.5	1195.0
				0.0
93.5	60.8	45.0	58.5	2205.0
60.7	39.5	31.5	38.5	1470.0
100.0	65.0	52.0	60.7	2341.0
74.7	48.6	33.7	47.2	1623.0
93.0	60.5	47.2	58.5	2227.0
85.5	55.6	40.7	54.2	2012.0
52.0	33.8	25.0	31.5	1195.0
65.5	42.6	31.5	40.7	1536.0
72.5	47.1	38.5	45.0	1735.0
				0.0
58.0	37.7	27.2	31.5	1217.0
67.7	44.0	33.7	40.7	1558.0
81.7	57.0	40.7	54.2	2033.0
87.7	57.0	40.7	54.2	2033.0
65.5	42.6	31.5	40.7	1536.0
45.0	29.3	20.2	27.2	1018.0
58.5	38.0	27.2		272.0
74.7	48.6	33.7	47.2	1753.0

Knee Flexion 1-RM (plates) 1 plate=12.5 lbs	Knee Flexion 1-RM (lbs)	Knee Flexion 1-RM (kg)	Knee Flexion 65% 1-RM	Sets Weight Used (lbs)	Sets Weight Used (kg)
20.0	250.0	113.6	175.0		
12.0	150.0	68.2	97.5	93.5	42.5
16.0	200.0	90.9	130.0	131.0	59.5
14.5	181.0	82.3	117.7	118.5	53.9
13.5	168.8	76.7	109.7	106.0	48.2
12.5	156.3	71.0	101.6	100.0	45.5
10.5	131.0	59.6	85.2	81.0	36.8
10.5	131.0	59.6	85.2	81.0	36.8
13.5	168.8	76.7	109.7	106.0	48.2
12.0	150.0	68.2	97.5	93.5	42.5
11.5	143.5	65.2	93.3	93.5	42.5
13.5	168.8	76.7	109.7	106.0	48.2
11.5	143.5	65.2	93.3	93.5	42.5
15.0	187.5	85.2	121.9	118.5	53.9
15.0	187.5	85.2	121.9	118.5	53.9
17.5	218.5	99.3	142.0	137.5	62.5
13.0	162.5	73.9	105.6	106.0	48.2
					0.0
					0.0
10.0	125.0	56.8	81.3	81.0	36.8
					0.0
14.0	175.0	79.6	113.8	112.5	51.1
9.0	112.5	51.1	73.1	68.5	31.1
11.5	143.5	65.2	93.3	87.5	39.8
					0.0
10.0	125.0	56.8	81.3	81.0	36.8
13.5	168.8	76.7	109.7	106.0	48.2
14.0	175.0	79.6	113.8	112.5	51.1
14.0	175.0	79.6	113.8	112.5	51.1
13.5	168.8	76.7	109.7	106.0	48.2
15.5	193.5	88.0	125.8	125.0	56.8
10.0	125.0	56.8	81.3	81.0	36.8
14.0	175.0	79.6	113.8	112.5	51.1
10.5	131.0	59.6	85.2	81.0	36.8
					0.0
11.5	143.5	65.2	93.3	93.5	42.5
15.5	193.5	88.0	125.8	125.0	56.8
16.5	206.0	93.6	133.9	131.0	59.5
15.0	187.5	85.2	121.9	118.5	53.9
15.0	187.5	85.2	121.9	118.5	53.9
8.0	100.0	45.5	65.0	62.5	28.4
13.0	162.5	73.9	105.6		0.0
15.0	187.5	85.2	121.9	118.5	53.9

Total Volume (Weight (kg)xSetsxReps)	Lat Pulldown 1-RM (plates)1 plate=12.5 lbs	Lat Pulldown 1-RM (lbs)	Lat Pulldown 1-RM (kg)	Lat Pulldown 65% 1RM	Sets Weight Used (lbs)
	14.0	175.0	79.6	113.8	
1275.0	9.0	112.5	51.1	73.1	68.9
1735.3	11.5	143.9	65.4	93.5	93.9
1615.9	11.5	143.9	65.4	93.5	93.9
1445.5	10.5	131.4	59.7	85.4	81.4
1363.6	13.0	162.5	73.9	105.6	106.4
1104.5	13.0	162.5	73.9	105.6	106.4
1104.5	12.0	150.0	68.2	97.5	93.9
1445.5	13.0	162.5	73.9	105.6	106.4
1275.0	9.5	118.9	54.1	77.3	75.0
1275.0	10.0	125.0	56.8	81.3	81.4
1445.5	14.5	181.4	82.5	117.9	118.9
1275.0	10.5	131.4	59.7	85.4	81.4
1615.9	11.5	143.9	65.4	93.5	93.9
1615.9	15.0	187.5	85.2	121.9	118.9
1875.0	14.5	181.4	82.5	117.9	118.9
1445.5	13.0	162.5	73.9	105.6	106.4
0.0					
0.0					
1104.5	9.5	118.9	54.1	77.3	75.0
0.0					
1534.1	14.0	175.0	79.6	113.8	112.5
934.1	8.5	106.4	48.4	69.2	68.5
1193.2	9.5	118.9	54.1	77.3	75.0
0.0					
1104.5	14.0	175.0	79.6	113.8	112.5
1445.5	11.5	143.9	65.4	93.5	93.9
1534.1	16.0	201.6	91.6	131.0	131.4
1534.1	11.5	143.9	65.4	93.5	93.9
1445.5	11.5	143.9	65.4	93.5	93.9
1704.5	15.0	187.5	85.2	121.9	118.9
1104.5	10.5	131.4	59.7	85.4	81.4
1534.1	11.0	137.5	62.5	89.4	87.5
1104.5	12.0	150.0	68.2	97.5	93.9
0.0					
1323.5	12.0	150.0	68.2	97.5	93.9
1704.5	13.0	162.5	73.9	105.6	106.4
1786.4	12.0	150.0	68.2	97.5	93.9
1615.9	13.5	168.9	76.8	109.8	106.4
1615.9	12.0	150.0	68.2	97.5	93.9
852.3	8.5	106.4	54.1	69.2	68.9
0.0	12.0	150.0	68.2	97.5	
1615.9	14.0	175.0	79.6	113.8	112.5

Sets Weight Used (kg)	Total Volume (Weight (kg)xSetsxReps)	Knee Extension 1-RM (plates) 1 plate = 12.5 lbs	Knee Extension 1-RM (lbs)	Knee Extension 1-RM (kg)	Knee Extension 65% 1-RM
		20.0	250.0	113.6	175.0
31.3	939.5	10.5	131.2	59.6	85.3
42.7	1280.5	14.5	181.3	82.4	117.8
42.7	1280.5	14.5	181.3	82.4	117.8
37.0	1110.0	12.5	156.2	71.0	101.5
48.4	1450.9	14.5	181.3	82.4	117.8
48.4	1450.9	12.5	156.2	71.0	101.5
42.7	1280.5	8.5	106.2	48.3	69.0
48.4	1450.9	14.5	181.3	82.4	117.8
34.1	1022.7	10.0	125.0	56.8	81.3
37.0	1110.0	13.5	168.7	76.7	109.7
54.0	1621.4	15.0	187.5	85.2	121.9
37.0	1110.0	10.5	131.2	59.6	85.3
42.7	1280.5	15.5	193.7	88.0	125.9
54.0	1621.4	17.5	218.7	99.4	142.2
54.0	1621.4	15.5	193.7	88.0	125.9
48.4	1450.9	13.0	162.5	73.9	105.6
0.0	0.0				
0.0	0.0				
34.1	1022.7	10.0	125.0	56.8	81.3
0.0	0.0				
51.1	1534.1	14.0	175.0	79.6	113.8
31.1	934.1	8.0	100.0	45.5	65.0
34.1	1022.7	8.5	106.2	48.3	69.0
0.0	0.0				
51.1	1534.1	12.5	156.2	71.0	101.5
42.7	1280.5	15.0	187.5	85.2	121.9
59.7	1791.8	9.0	112.5	51.1	73.1
42.7	1280.5	16.5	206.2	93.7	134.0
42.7	1280.5	14.5	181.3	82.4	117.8
54.0	1621.4	17.0	212.5	96.6	138.1
37.0	1110.0	10.0	125.0	96.6	81.3
39.8	1193.2	10.0	125.0	56.8	81.3
42.7	1280.5	11.0	137.5	62.5	89.4
0.0	0.0				
42.7	1280.5	10.5	131.2	59.6	85.3
48.4	1450.9	13.5	168.7	76.7	109.7
42.7	1280.5	19.0	237.5	108.0	154.4
48.4	1450.9	16.5	206.2	93.7	134.0
42.7	1280.5	13.5	168.7	76.7	109.7
31.3	939.5	8.5	106.2	48.3	69.0
0.0	0.0	10.5	131.2	59.6	85.3
51.1	1534.1	14.5	181.3	82.4	117.8

Sets Weight Used (lbs)	Sets Weight Used (kg)	Total Volume (Weight (kg)xSetsxReps)	Total Exercise Volume (kg)
81.2	36.9	1107.3	7430.7
118.7	54.0	1618.6	9599.6
118.5	53.9	1615.9	9047.0
100.0	45.5	1363.6	8193.0
118.7	54.0	1618.6	10000.0
100.0	45.5	1363.6	9309.0
68.7	31.2	936.8	6561.6
118.7	54.0	1618.6	9725.5
81.2	36.9	1107.3	7185.5
106.2	48.3	1448.2	8720.0
118.7	54.0	1618.6	10475.9
0.0	0.0	0.0	6481.8
125.0	56.8	1704.5	9183.8
137.5	62.5	1818.0	11091.2
125.0	56.8	1704.5	11022.5
106.2	48.3	1448.2	9718.8
	0.0	0.0	0.0
	0.0	0.0	0.0
81.2	36.9	1107.3	7111.8
	0.0	0.0	0.0
112.5	51.1	1534.1	11466.0
62.5	28.4	852.3	5872.3
68.7	31.2	824.3	6642.5
	0.0	0.0	0.0
100.0	45.5	1192.5	9028.9
118.7	54.0	1618.6	8541.8
68.7	31.2	936.8	10232.8
112.5	51.1	1307.4	9010.4
112.5	51.1	1534.1	10621.5
137.5	62.5	1875.0	11478.4
87.5	39.8	1193.2	7504.5
81.2	36.9	1107.3	8956.0
87.5	39.8	1193.2	8720.5
	0.0	0.0	0.0
81.2	36.9	1107.3	7291.9
106.2	48.3	1363.5	8662.4
240.0	109.1	2908.9	13506.9
131.2	59.6	1675.6	10546.3
106.2	48.3	1448.2	8971.5
68.7	31.2	936.8	6283.0
	0.0	0.0	908.4
112.5	51.1	1534.1	10208.0

Subject ID	Age (years)	Group	QuadMTH1a	QuadMTH1b	QuadAvg1	HamstringMTH1a	Hamstring MTH1b	HamAvg1
RD1	28.0	1	5.72	5.74	5.73	5.92	5.94	5.93
RD2	65.9	3	5.78	5.78	5.78	6.86	6.82	6.84
RD3	27.7	1	6.14	6.05	6.10	4.73	4.78	4.76
RD4	60.0	3	5.87	5.87	5.87	5.81	5.81	5.81
RD5	22.5	1	5.08	5.12	5.10	6.56	6.58	6.57
RD6	32.8	1	6.08	6.1	6.09	4.84	4.86	4.85
RD7	72.3	3	4.24	4.16	4.20	5.36	5.36	5.36
RD8	75.6	3	3.82	3.8	3.81	5.87	5.90	5.89
RD9	43.2	2	4.52	4.59	4.56	5.96	6.17	6.07
RD10	74.9	3	4.86	4.9	4.88	6.12	6.06	6.09
RD11	26.8	1	4.83	4.87	4.85	5.37	5.39	5.38
RD12	22.5	1	5.37	5.41	5.39	5.92	5.95	5.94
RD13	71.2	3	4.82	4.82	4.82	6.64	6.60	6.62
RD14	46.0	2	5.46	5.48	5.47	6.10	6.12	6.11
RD15	27.2	1	6.08	6.06	6.07	6.12	6.12	6.12
RD16	49.8	2	4.9	4.9	4.90	6.40	6.40	6.40
RD17	61.2	3	4.5	4.5	4.50	5.85	5.93	5.89
RD18								
RD19								
RD20	47.3	2	4.57	4.53	4.55	5.80	5.80	5.80
RD21								
RD22	21.7	1	5.98	5.98	5.98	6.48	6.46	6.47
RD23	60.3	3	3.86	3.86	3.86	5.01	5.02	5.02
RD24	61.3	3	4.17	4.22	4.20	5.57	5.65	5.61
RD25								
RD26	56.1	2	5.06	5.06	5.06	5.79	5.76	5.78
RD27	53.5	2	4.32	4.29	4.31	6.22	6.30	6.26
RD28	46.8	2	5.09	5.09	5.09	5.98	5.98	5.98
RD29	27.0	1	4.81	4.83	4.82	6.40	6.36	6.38
RD30	29.0	1	5.02	5.02	5.02	5.92	5.92	5.92
RD31	29.8	1	5.8	5.8	5.80	6.62	6.57	6.60
RD32	27.2	1	4.62	4.64	4.63	6.75	6.75	6.75
RD33	57.2	2	4.59	4.64	4.62	5.74	5.72	5.73
RD34	48.8	2	5.82	5.8	5.81	6.84	6.62	6.73
RD35								
RD36	71.1	3	4.17		4.17	7.22	7.27	7.25
RD37	51.6	2	4.74	4.74	4.74	5.16	5.24	5.20
RD38	40.8	2	6.34	6.42	6.38	6.17	6.19	6.18
RD39	44.0	2	5.51	5.44	5.48	5.96	6.00	5.98
RD40	48.9	2	5.55	5.58	5.57	6.32	6.32	6.32
RD41	57.0	2	4.52	4.48	4.50	5.18	5.24	5.21
RD42								
RD43	24.2	1	5.82	5.84	5.83	6.10	6.16	6.13

BicepsMTH1a	BicepsMTH1b	BicepsAvg1	TricepsMTH1a	TricepsMTH1b	TricepsAvg1	QuadMTH2a	QuadMTH2b	QuadAvg2
3.66	3.63	3.65	4.32	4.22	4.27	5.78	5.78	5.78
4.28	4.26	4.27	3.36	3.48	3.42	5.62	5.6	5.61
3.8	3.78	3.79	3.89	3.94	3.92	5.94	5.96	5.95
4.22	4.22	4.22	4.08	4.17	4.13	5.58	5.8	5.69
3.18	3.18	3.18	3.05	3.07	3.06	5.24	5.28	5.26
3.23	3.32	3.28	4.15	4.19	4.17	6.38	6.38	6.38
3.99	3.97	3.98	3.90	3.94	3.92	4.29	4.41	4.35
3.78	3.86	3.82	3.83	3.93	3.88	3.73	3.78	3.76
4.45	4.52	4.49	3.78	3.76	3.77	4.67	4.62	4.65
3.08	3.11	3.10	2.78	2.72	2.75	4.49	4.50	4.50
3.31	3.30	3.31	3.69	3.71	3.70	4.74	4.78	4.76
3.05	3.10	3.08	4.55	4.55	4.55	5.13	5.08	5.11
3.72	3.74	3.73	2.53	2.53	2.53	4.81	4.78	4.80
3.10	3.02	3.06	3.34	3.28	3.31	5.36	5.30	5.33
3.52	3.52	3.52	3.76	3.75	3.76	6.01	5.96	5.99
4.16	4.14	4.15	4.43	4.41	4.42	4.95	5.01	4.98
3.96	3.94	3.95	4.17	4.06	4.12	4.60	4.60	4.60
2.94	2.94	2.94	3.56	3.54	3.55	4.80	4.78	4.79
3.64	3.69	3.67	4.55	4.55	4.55	6.14	6.20	6.17
3.53	3.60	3.57	1.49	1.50	1.50	3.80	3.81	3.81
3.71	3.66	3.69	3.42	3.41	3.42	4.48	4.40	4.44
4.38	4.35	4.37	4.39	4.39	4.39	5.17	5.18	5.18
3.78	3.74	3.76	3.50	3.47	3.49	4.52	4.50	4.51
4.81	4.85	4.83	3.99	3.96	3.98	5.13	5.18	5.16
3.44	3.47	3.46	3.68	3.69	3.69	4.85	4.83	4.84
4.02	3.99	4.01	4.66	4.69	4.68	5.04	5.06	5.05
3.83	3.82	3.83	4.08	4.10	4.09	5.92	5.92	5.92
3.26	3.31	3.29	3.21	3.21	3.21	4.95	4.95	4.95
3.78	3.75	3.77	3.21	3.24	3.23	4.66	4.60	4.63
4.20	4.20	4.20	3.92	3.99	3.96	5.32	5.28	5.30
3.83	3.86	3.85	3.27	3.33	3.30	4.22	4.22	4.22
3.60	3.60	3.60	3.80	3.75	3.78	5.01	5.04	5.03
3.80	3.84	3.82	4.10	4.05	4.08	6.44	6.40	6.42
4.35	4.41	4.38	4.57	4.55	4.56	5.92	5.94	5.93
3.62	3.63	3.63	4.96	4.92	4.94	5.86	5.88	5.87
3.65	3.52	3.59	3.75	3.69	3.72	4.83	4.81	4.82
3.14	3.10	3.12	2.93	2.88	2.91	5.58	5.58	5.58

HamstringMTH2a	HamstringMTH2b	HamAvg2	BicepsMTH2a	BicepsMTH2b	BicepsAvg2	TricepsMTH2a	TricepsMTH2a	TicepsAvg2
5.94	6.01	5.98	3.66	3.74	3.70	4.25	3.89 (bad)	4.25
6.44	6.44	6.44	4.26	4.23	4.25	3.36	3.38	3.37
4.73	4.75	4.74	4.04	4.03	4.04	3.71	3.73	3.72
5.6	5.64	5.62	4.14	4.14	4.14	4.22	4.15	4.19
6.24	6.28	6.26	3.03	3.01	3.02	3.33	3.31	3.32
4.68	4.66	4.67	3.30	3.33	3.32	4.23	4.20	4.22
4.99	5.08	5.04	4.08	4.04	4.06	3.90	3.95	3.93
6.02	6.00	6.01	3.47	3.44	3.46	3.62	3.59	3.61
x	x	#DIV/0!	4.37	4.28	4.33	3.95	3.92	3.94
5.69	5.74	5.72	3.06	3.03	3.05	2.75	2.87	2.81
5.51	5.46	5.49	3.30	3.30	3.30	3.59	3.60	3.60
5.64	5.69	5.67	3.26	3.21	3.24	4.52	4.50	4.51
6.73	6.73	6.73	4.01	3.99	4.00	2.70	2.73	2.72
5.93	5.79	5.86	3.19	3.23	3.21	3.11	3.08	3.10
6.24	6.26	6.25	3.72	3.74	3.73	3.42	3.53	3.48
6.56	6.56	6.56	4.10	4.10	4.10	4.66	4.64	4.65
6.48	6.44	6.46	3.78	3.80	3.79	4.17	4.15	4.16
5.43	5.47	5.45	3.27	3.21	3.24	3.47	3.51	3.49
6.48	6.53	6.51	3.81	3.79	3.80	4.38	4.53	4.46
4.95	4.96	4.96	3.55	3.51	3.53	1.80	1.88	1.84
5.28	5.32	5.30	3.73	3.71	3.72	3.30	3.24	3.27
6.22	6.20	6.21	4.14	4.13	4.14	4.64	4.64	4.64
6.14	6.14	6.14	3.59	3.54	3.57	3.87	3.84	3.86
5.90	5.91	5.91	4.73	4.71	4.72	4.35	4.38	4.37
6.89	6.89	6.89	3.54	3.54	3.54	3.56	3.50	3.53
6.19	6.19	6.19	3.87	3.92	3.90	4.50	4.52	4.51
6.53	6.42	6.48	3.83	3.83	3.83	4.36	4.31	4.34
6.64	6.60	6.62	3.26	3.24	3.25	3.33	3.40	3.37
5.88	5.79	5.84	3.55	3.62	3.59	3.54	3.53	3.54
6.80	6.75	6.78	4.22	4.27	4.25	3.90	3.92	3.91
6.93	7.29	7.11	3.90	3.90	3.90	3.27	3.32	3.30
5.16	5.23	5.20	3.54	3.56	3.55	3.78	3.80	3.79
6.50	6.46	6.48	3.87	3.84	3.86	4.13	4.16	4.15
6.04	6.06	6.05	4.50	4.46	4.48	4.64	4.62	4.63
5.90	5.83	5.87	3.35	3.35	3.35	5.11	5.05	5.08
5.32	5.33	5.33	3.68	3.57	3.63	3.77	3.73	3.75
6.28	6.30	6.29	3.03	3.08	3.06	3.51	3.54	3.53

Subject ID	Age (years)	Group	Height (cm)	Weight (kg)	BMI (kg/m2)	BodySurfaceArea Dubois Formula (m2)	Young Adult BMC t-score	Total BF%
RD1	28.0	1	185.0	83.6	24.4	2.1	1.7	19.2
RD2	65.9	3	174.0	77.5	25.6	1.9	2.6	19.0
RD3	27.7	1	171.5	79.0	26.9	1.9	1.3	34.7
RD4	60.0	3	185.0	99.1	29.0	2.2	0.5	34.1
RD5	22.5	1	179.0	77.9	25.7	2.0	-0.9	25.7
RD6	32.8	1	175.3	67.2	22.0	1.8	-0.3	9.1
RD7	72.3	3	161.5	74.5	28.6	1.8	1.2	25.0
RD8	75.6	3	173.5	69.8	23.2	1.8	2.1	23.2
RD9	43.2	2	179.5	87.9	27.3	2.1	0.8	29.7
RD10	74.9	3	182.0	74.9	22.6	2.0	-0.9	19.9
RD11	26.8	1	167.0	59.3	21.3	1.7	-0.2	24.0
RD12	22.5	1	171.5	68.6	23.3	1.8	0.1	17.2
RD13	71.2	3	176.5	79.8	25.6	2.0	1.7	27.8
RD14	46.0	2	190.0	74.2	20.6	2.0	-0.2	7.9
RD15	27.2	1	189.0	89.7	25.1	2.2	1.7	23.7
RD16	49.8	2	179.5	85.4	26.5	2.0	3.3	25.4
RD17	61.2	3	172.5	87.6	29.4	2.0	0.9	30.9
RD18						0.0		
RD19						0.0		
RD20	47.3	2	167.0	62.2	22.3	1.7	-0.2	19.3
RD21						0.0		
RD22	21.7	1	178.0	78.7	24.8	2.0	2.5	17.9
RD23	60.3	3	185.5	64.4	18.7	1.9	-0.3	12.7
RD24	61.3	3	181.7	79.6	24.1	2.0	0.9	31.0
RD25						0.0		
RD26	56.1	2	167.0	77.7	27.9	1.9	1.1	25.1
RD27	53.5	2	178.0	70.4	22.2	1.9	0.8	16.2
RD28	46.8	2	179.0	76.8	24.0	2.0	0.8	13.8
RD29	27.0	1	172.5	77.3	26.0	1.9	1.1	22.0
RD30	29.0	1	169.0	74.5	26.1	1.9	1.3	22.5
RD31	29.8	1	176.0	75.8	24.5	1.9	0.1	19.1
RD32	27.2	1	177.0	73.0	23.3	1.9	-0.6	24.9
RD33	57.2	2	185.5	99.8	29.0	2.2	2.0	33.1
RD34	48.8	2	173.5	89.4	29.7	2.0	1.1	35.7
RD35						0.0		
RD36	71.1	3	182.3	69.0	20.8	1.9	3.5	12.0
RD37	51.6	2	186.0	84.1	24.3	2.1	0.6	23.4
RD38	40.8	2	176.5	83.3	26.7	2.0	0.3	19.6
RD39	44.0	2	185.0	94.4	27.6	2.2	1.7	28.7
RD40	48.9	2	177.5	80.8	25.6	2.0	0.1	16.4
RD41	57.0	2	170.0	77.3	26.7	1.9	-0.5	36.4
RD42						0.0		
RD43	24.2	1	181.5	73.9	22.4	1.9	0.7	19.2

Total Mass (kg)	TotalTissue (g)	TotalFat(g)	Total Lean (g)	Total BMC (g)	Total Fat Free (g)	Android %fat	Gynoid%fat
83.8	79969.0	15326.0	64644.0	3828.0	68471.0	24.0	23.8
77.6	74233.0	14118.0	60115.0	3344.0	63460.0	31.3	22.2
78.6	75134.0	26056.0	49078.0	3459.0	52537.0	37.4	46.5
98.7	95257.0	32468.0	62789.0	3398.0	66187.0	47.1	33.6
77.5	74877.0	19264.0	55612.0	2620.0	58233.0	35.3	31.0
67.6	64846.0	5900.0	58947.0	2773.0	61720.0	13.1	12.2
74.2	71207.0	17781.0	53427.0	3008.0	56435.0	39.7	24.8
69.7	66342.0	15384.0	50958.0	3337.0	54295.0	36.3	26.1
87.8	84366.0	25090.0	59276.0	3484.0	62760.0	40.7	35.3
74.9	72098.0	14343.0	57755.0	2833.0	60588.0	24.9	25.9
59.2	56549.0	13597.0	42953.0	2690.0	45643.0	30.7	29.9
68.7	65722.0	11307.0	54415.0	2967.0	57382.0	25.2	23.3
79.8	76344.0	21255.0	55089.0	3494.0	58583.0	41.0	28.9
74.9	71600.0	5671.0	65929.0	3338.0	69267.0	9.8	11.6
89.9	85864.0	20379.0	65485.0	3930.0	69415.0	32.5	29.6
85.4	81284.0	20642.0	60643.0	4121.0	64764.0	34.7	33.2
87.3	84027.0	25923.0	58104.0	3242.0	61346.0	43.7	34.2
62.2	59686.0	11518.0	48167.0	2497.0	50664.0	19.1	29.7
78.9	75191.0	13464.0	61728.0	3697.0	65425.0	23.7	24.0
65.1	62220.0	7929.0	54291.0	2834.0	57125.0	15.7	20.6
79.4	75849.0	23490.0	52359.0	3535.0	55894.0	39.8	35.3
77.6	74597.0	18708.0	55890.0	3039.0	58929.0	40.3	24.1
70.7	67700.0	10958.0	56743.0	2969.0	59712.0	22.4	21.4
77.2	73929.0	10236.0	63693.0	3226.0	66919.0	16.1	18.7
77.1	73665.0	16189.0	57476.0	3461.0	60937.0	27.6	28.9
74.4	71144.0	15993.0	55151.0	3223.0	58374.0	32.6	29.6
76.1	73001.0	13932.0	59070.0	3078.0	62148.0	22.8	26.0
72.8	69905.0	17405.0	52500.0	2860.0	55359.0	32.1	31.2
99.7	95703.0	31718.0	63985.0	3995.0	67980.0	45.9	33.7
88.9	85510.0	30529.0	54981.0	3435.0	58416.0	46.7	37.8
69.4	65396.0	7858.0	57538.0	4016.0	61554.0	15.5	18.1
84.1	80440.0	18814.0	61627.0	3612.0	65239.0	30.3	29.2
83.6	80459.0	15777.0	64682.0	3106.0	67788.0	31.6	23.9
97.4	93643.0	26893.0	66750.0	3710.0	70460.0	41.2	30.0
81.3	78307.0	12822.0	65485.0	2993.0	68478.0	22.4	21.9
76.3	73681.0	26852.0	46829.0	2662.0	49491.0	50.2	37.2
74.6	71517.0	13751.0	57766.0	3107.0	60873.0	23.5	27.5

A_G ratio	Arms Tissue BF%	ArmsTissue (g)	ArmsFat(g)	Arms Lean (g)	Arms BMC (g)	Arms Total Mass (kg)	Legs Tissue BF%
1.0	11.3	8663.0	980.0	7683.0	476.0	9.1	17.1
1.4	12.8	7486.0	962.0	6524.0	482.0	8.0	12.1
0.8	24.3	7901.0	1922.0	5979.0	449.0	8.3	36.8
1.4	21.0	9652.0	2029.0	7623.0	454.0	10.0	26.4
1.1	20.4	7721.0	1575.0	6146.0	339.0	8.1	22.1
1.1	5.6	6985.0	389.0	6595.0	332.0	7.3	8.5
1.6	16.7	7763.0	1296.0	6467.0	428.0	8.2	16.5
1.4	19.0	7216.0	1372.0	5843.0	478.0	7.7	19.4
1.2	20.4	9920.0	2022.0	7898.0	511.0	10.4	28.2
1.0	15.3	7819.0	1197.0	6623.0	428.0	8.2	21.8
1.0	14.9	5826.0	866.0	4959.0	345.0	6.2	24.0
1.1	10.9	7658.0	837.0	6821.0	467.0	8.1	15.6
1.4	18.7	7883.0	1471.0	6412.0	465.0	8.3	23.0
0.8	4.7	7586.0	354.0	7232.0	486.0	8.1	7.6
1.1	12.2	9480.0	1153.0	8327.0	541.0	10.0	23.8
1.0	14.5	9065.0	1311.0	7754.0	549.0	9.6	23.4
1.3	20.9	9220.0	1931.0	7289.0	417.0	9.6	27.0
0.6	12.5	6398.0	801.0	5597.0	357.0	6.8	22.5
1.0	9.2	8593.0	795.0	7799.0	468.0	9.1	18.3
0.8	8.3	6421.0	530.0	5890.0	423.0	6.8	13.2
1.1	25.6	7847.0	2009.0	5832.0	457.0	8.3	28.7
1.7	18.0	7875.0	1417.0	6458.0	409.0	8.3	17.8
1.1	12.3	7195.0	885.0	6310.0	444.0	7.6	14.3
0.9	8.9	9049.0	801.0	8247.0	451.0	9.5	14.3
1.0	14.6	8194.0	1197.0	6996.0	458.0	8.7	20.5
1.1	13.9	8568.0	1188.0	7380.0	417.0	9.0	19.0
0.9	14.4	8543.0	1234.0	7309.0	450.0	9.0	21.3
1.0	18.6	6757.0	1259.0	5497.0	323.0	7.1	25.0
1.4	25.1	10179.0	2559.0	7620.0	582.0	10.8	25.8
1.2	26.7	9338.0	2497.0	6842.0	461.0	9.8	31.2
0.9	6.7	7306.0	492.0	6814.0	586.0	7.9	11.2
1.0	15.7	8842.0	1388.0	7455.0	539.0	9.4	19.9
1.3	11.2	8458.0	949.0	7510.0	415.0	8.9	15.7
1.4	20.2	9880.0	1997.0	7884.0	543.0	10.4	19.3
1.0	9.4	8527.0	800.0	7727.0	443.0	9.0	13.3
1.4	25.2	7185.0	1807.0	5377.0	333.0	7.5	28.7
0.9	12.1	7130.0	864.0	6265.0	342.0	7.5	20.4

LegsTissue (g)	LegsFat(g)	Legs Lean (g)	Legs BMC (g)	Legs Total Mass (kg)	Trunk BF%
25729.0	4400.0	21329.0	1478.0	27.2	23.0
20947.0	2533.0	18415.0	1315.0	22.3	24.6
27939.0	10292.0	17647.0	1300.0	29.2	37.4
29936.0	7894.0	22042.0	1199.0	31.1	43.0
23311.0	5150.0	18162.0	990.0	24.3	30.4
21248.0	1799.0	19449.0	1021.0	22.3	10.5
19746.0	3255.0	16941.0	1132.0	20.9	32.1
19934.0	3875.0	16059.0	1387.0	21.3	27.6
27286.0	7694.0	19592.0	1324.0	28.6	34.7
22812.0	4976.0	17837.0	1097.0	23.9	20.7
17941.0	4305.0	13636.0	995.0	18.9	27.4
19273.0	3013.0	16261.0	1073.0	20.3	20.4
21191.0	4871.0	16319.0	1308.0	22.5	33.4
22515.0	1712.0	20803.0	1344.0	23.9	8.9
26567.0	6323.0	20244.0	1433.0	28.0	27.6
27172.0	6347.0	20826.0	1605.0	28.8	30.8
25536.0	6907.0	18629.0	1311.0	26.8	36.7
20282.0	4563.0	15719.0	970.0	21.3	19.7
23315.0	4274.0	19041.0	1307.0	24.6	20.7
18902.0	2491.0	16411.0	1193.0	20.1	13.6
22515.0	6463.0	16052.0	1339.0	23.9	35.0
21026.0	3745.0	17281.0	1223.0	22.2	31.6
21636.0	3104.0	18532.0	1226.0	22.9	19.0
24532.0	3499.0	21033.0	1214.0	25.7	15.4
24339.0	4985.0	19353.0	1328.0	25.7	25.8
22512.0	4281.0	18231.0	1183.0	23.7	28.3
24780.0	5276.0	19504.0	1250.0	26.0	19.7
22908.0	5724.0	17184.0	1057.0	24.0	27.6
30024.0	7745.0	22279.0	1540.0	31.6	40.7
26193.0	8183.0	18011.0	1279.0	27.5	41.9
19186.0	2142.0	17044.0	1506.0	20.7	14.1
24817.0	4934.0	19884.0	1344.0	26.2	28.4
25483.0	4002.0	21482.0	1277.0	26.8	24.7
27618.0	5341.0	22276.0	1447.0	29.1	37.1
24401.0	3251.0	21150.0	1235.0	25.6	20.5
21285.0	6109.0	15175.0	954.0	22.2	44.5
22779.0	4636.0	18143.0	1278.0	24.1	21.0

TrunkTissue (g)	TrunkFat(g)	Trunk Lean (g)	Trunk BMC (g)	Trunk Total Mass (kg)
40957.0	9431.0	31526.0	1356.0	42.3
40926.0	10086.0	30840.0	1048.0	42.0
35089.0	13123.0	21966.0	1181.0	36.3
50440.0	21668.0	28771.0	1232.0	51.7
39213.0	11931.0	27282.0	805.0	40.0
32301.0	3389.0	28912.0	840.0	33.1
39356.0	12649.0	26707.0	954.0	40.3
34745.0	9573.0	25172.0	915.0	35.7
42067.0	14603.0	27464.0	1105.0	43.2
36662.0	7598.0	29064.0	808.0	37.5
28700.0	7871.0	20829.0	895.0	29.6
34321.0	7007.0	27313.0	959.0	35.3
42524.0	14213.0	28310.0	1178.0	43.7
36709.0	3269.0	33440.0	987.0	37.7
44487.0	12263.0	32224.0	1363.0	45.8
40112.0	12346.0	27767.0	1394.0	41.5
44458.0	16331.0	28127.0	1129.0	45.6
28821.0	5679.0	23142.0	696.0	29.5
37944.0	7851.0	30093.0	1297.0	39.2
32658.0	4524.0	28135.0	696.0	33.4
40728.0	14237.0	26491.0	1213.0	41.9
41044.0	12958.0	28086.0	939.0	42.0
34404.0	6536.0	27868.0	832.0	35.2
35852.0	5519.0	30333.0	1048.0	36.9
36769.0	9469.0	27301.0	1212.0	38.0
35350.0	9996.0	25355.0	1033.0	36.4
35143.0	6912.0	28231.0	924.0	36.1
35173.0	9725.0	25449.0	942.0	36.1
50538.0	20574.0	29964.0	1315.0	51.9
45359.0	19025.0	26334.0	1211.0	46.6
34140.0	4810.0	29330.0	1260.0	35.4
41764.0	11875.0	29889.0	1151.0	42.9
41501.0	10271.0	31230.0	964.0	42.5
50616.0	18754.0	31862.0	1160.0	51.8
40397.0	8289.0	32108.0	854.0	41.3
40776.0	18131.0	22645.0	919.0	41.7
36645.0	7701.0	28994.0	970.0	37.6

Subject ID	Age (years)	Group	Urine Specific Gravity	Right ABI	Left ABI
RD1	28.0	1	1.015	1.1	1.04
RD2	65.9	3	1.006	1.4	1.3
RD3	27.7	1	1.018	1.05	1.19
RD4	60.0	3	1.014	1.22	1.04
RD5	22.5	1	1.021	1.09	1.15
RD6	32.8	1	1.004	1.18	1.24
RD7	72.3	3	1.007	0.99	1.07
RD8	75.6	3	1.023	1.25	0.99
RD9	43.2	2	1.017	1.12	1.12
RD10	74.9	3	1.013	1.2	1.2
RD11	26.8	1	1.022	0.97	
RD12	22.5	1	1.022	1.13	1.12
RD13	71.2	3	1.015	1.14	1.19
RD14	46.0	2	1.005	1.1	0.96
RD15	27.2	1	1.018	1.09	1.02
RD16	49.8	2	1.016	1.29	1.17
RD17	61.2	3	1.022	1.35	1.37
RD18					
RD19					
RD20	47.3	2	1.014	1.18	1.2
RD21					
RD22	21.7	1	1.008	1.07	1.07
RD23	60.3	3	1.027	1.23	1.27
RD24	61.3	3	1.023	1.15	1.22
RD25					
RD26	56.1	2	1.015	1.27	1.34
RD27	53.5	2	1.005	1.13	1.2
RD28	46.8	2	1.018	1.09	1.09
RD29	27.0	1	1.011	1.18	1.16
RD30	29.0	1	1.023	1	0.97
RD31	29.8	1	1.008	1.04	1.11
RD32	27.2	1	1.012	1.03	1.14
RD33	57.2	2		1.25	1.19
RD34	48.8	2	1.006	1.19	1.2
RD35					
RD36	71.1	3	1.012	1.23	1.27
RD37	51.6	2	1.02	1.15	1.15
RD38	40.8	2	1.005	1.06	1.06
RD39	44.0	2	1.008	1.19	1.19
RD40	48.9	2	1.006	1.12	1.12
RD41	57.0	2	1.019	1.28	1.26
RD42			1.023	1.2	1.02
RD43	24.2	1	1.027	1.11	1.08

Patient ID	Group	Operator Index	PreEX_P_SP	PreEX_P_DP	PreEX_P_MEANP	PreEX_P_AI	PreEX_C_AP	PreEX_C_AP_HR75	PreEX_HR	PreEX_C_AGPH	PreEX_C_AGPH_HR75	PreEX_C_T1R	PreEX_C_SP
RD2	3	100	135	86	105	84	12	8	60	29	22	146	127
RD3	1	99	121	69	85	51	1	-2	51	4	-8	201	102
RD4	3	100	127	70	87	71	5	4	67	13	10	162	111
RD5	1	92	137	72	86	16	-7	-8	70	-19	-21	166	110
RD6	1	92	111	63	76	48	-1	-5	45	-3	-17	174	92
RD07	3	95	139	82	106	75	12	13	81	27	30	128	127
RD8	3	98	140	81	102	106	21	14	57	41	32	129	133
RD9	2	100	122	74	90	75	7	3	58	18	10	167	111
RD10	3	100	111	71	83	60	4	0	46	14	0	157	99
RD11	1	91	113	74	85	41	-1	-2	72	-5	-7	151	97
RD12	1	92	125	81	95	43	-1	-2	60	-2	-9	152	107
RD13	3	100	133	86	103	78	9	7	65	25	20	140	123
RD14	2	98	120	80	93	61	3	1	61	12	6	159	108
RD15	1	95	125	72	91	64	3	-2	46	9	-5	196	110
RD16	2	92	108	71	85	81	8	4	50	28	15	152	102
RD17	3	94	117	81	93	84	9	5	48	30	17	158	112
RD20	2	95	110	68	83	68	5	1	49	16	4	186	100
RD22	1	90	134	69	88	37	-4	-5	66	-10	-14	210	108
RD23	3	98	106	64	74	52	3	-1	46	10	-4	145	91
RD24	3	100	118	80	95	83	6	2	52	20	9	192	112
RD26	2	100	127	71	90	71	5	0	47	12	-1	192	114
RD27	2	100	116	71	88	74	9	4	49	25	12	154	107
RD28	2	100	120	72	90	79	9	3	50	23	10	168	111
RD29	1	99	132	78	95	62	5	1	55	13	4	152	115
RD30	1	100	120	72	86	37	-2	-1	77	-6	-5	153	100
RD31	1	100	113	69	82	47	0	-3	56	-1	-10	176	96
RD32	1	97	124	69	85	42	0	-3	58	-1	-9	174	103
RD33	2	100	120	78	93	73	5	1	50	14	2	202	111
RD34	2	92	108	73	84	72	5	0	42	18	2	176	100
RD36	3	100	118	73	88	82	11	5	50	28	16	150	111
RD37	2	100	124	69	88	63	2	3	78	6	7	167	106
RD38	2	100	127	85	98	65	4	2	63	14	8	161	115
RD39	2	97	131	85	102	79	9	5	57	24	16	158	122
RD40	2	100	121	67	84	61	5	2	59	12	5	167	106
RD41	2	100	132	82	99	80	10	8	66	26	22	146	122
RD43	1	100	134	74	89	40	-3	-6	57	-9	-18	151	109

PreEX _C_D P	PreEX_C_ MEANP	PreEX_ C_AI	PostEx_Operat or Index	PostEx_ P_SP	PostEx_ P_DP	PostEx_P_ MEANP	PostEx_ P_AI	PostEx_ C_AP	PostEx_ C_AP_ HR75
87	105	140	100	145	85	106	73	10	7
70	85	104	100	128	70	88	48	0	2
71	87	115	99	131	67	86	9999	4	8
72	86	81	98	136	61	79	25	-5	-1
63	76	97	100	122	62	79	40	-1	-1
84	106	137	100	138	68	87	9999	0	6
82	102	169	97	140	80	103	80	9	14
75	90	122	100	130	67	86	63	4	4
71	83	116	100	125	71	86	54	3	-1
75	85	95	100	103	61	75	55	1	5
82	95	98	99	143	89	106	44	-1	2
87	103	133	100	133	82	99	68	4	5
81	93	114	100	132	76	94	58	3	4
73	91	110	98	130	64	81	9999	-5	-1
72	85	138	93	113	64	80	63	8	4
81	93	143	99	132	71	89	9999	3	6
69	83	119	94	121	69	86	59	4	0
71	88	90	100	143	62	83	28	-6	-2
64	74	111	97	105	67	78	50	2	0
81	95	125	100	124	75	92	74	2	2
72	90	114	97	124	66	82	53	3	-2
72	88	133	100	123	67	84	55	4	1
73	90	129	100	129	65	83	47	1	-1
79	95	116	100	145	79	98	45	-1	-1
73	86	94	98	133	60	78	29	-4	2
70	82	99	100	121	62	78	37	-3	-1
70	85	99	97	126	64	80	40	0	0
78	93	117	97	121	69	86	59	-1	-3
73	84	122	98	108	56	74	55	10	8
73	88	140	98	122	75	91	69	6	3
71	88	106	100	124	70	86	9999	-1	2
85	98	116	100	137	74	92	9999	2	5
86	102	132	100	133	79	97	68	8	8
68	84	114	95	130	69	87	56	2	-1
83	99	135	96	128	77	95	9999	5	8
75	89	91	99	149	69	93	41	1	2

PostEx_HR	PostEx_C_AGPH	PostEx_C_AGPH_HR75	PostEx_C_T1R	PostEx_C_SP	PostEx_C_DP	PostEx_C_MEANP	PostEx_C_AI	PreCon_Operator Index	PreCon_P_SP	PreCon_P_DP
66	22	17	149	131	87	106	128	100	143	92
91	-1	7	146	105	74	88	99	97	118	71
90	9	16	165	112	69	86	109	98	120	68
91	-11	-3	162	106	63	79	89	94	126	68
74	-3	-4	181	100	63	79	97	98	110	62
100	1	13	140	110	70	87	101	100	128	80
91	22	30	143	125	83	103	129	100	136	81
75	9	10	177	111	69	86	110	95	118	75
52	9	-2	165	108	72	86	110	98	127	79
98	4	16	172	89	62	75	105	93	106	72
91	-3	5	161	123	92	106	97	100	118	75
81	13	16	147	117	83	99	115	100	129	77
83	8	11	173	114	78	94	109	98	126	84
94	-12	-4	182	105	66	81	88	91	141	77
60	21	13	9999	101	65	80	126	95	111	68
87	8	14	162	113	73	89	109	92	118	78
53	11	0	174	106	70	86	112	94	108	71
94	-14	-5	160	111	66	83	86	100	130	75
58	10	2	143	92	68	78	111	100	108	64
74	5	4	196	112	76	92	105	100	114	80
47	7	-7	159	103	66	82	107	99	131	77
60	10	3	159	105	68	84	111	100	119	76
65	3	-2	172	106	66	83	103	95	116	64
76	-3	-2	163	119	81	98	97	98	129	68
107	-10	5	146	103	62	78	90	99	117	64
93	-10	-2	158	97	64	78	90	100	111	66
77	-1	0	162	102	65	80	99	97	124	71
61	-2	-8	209	107	70	86	98	95	120	78
67	26	22	9999	95	57	74	135	98	110	72
57	18	10	154	110	76	91	122	94	123	76
91	-2	6	159	103	72	86	98	100	113	66
90	4	12	159	114	76	92	104	95	138	88
75	20	20	139	119	80	97	125	99	120	83
62	5	-1	182	111	70	87	105	100	123	68
89	15	22	139	113	80	95	118	98	136	85
78	3	4	146	118	71	93	103	100	131	73

PreCon_P_MEANP	PreCon_P_AI	PreCon_C_AP	PreCon_C_AP_HR75	PreCon_HR	PreCon_C_AGPH	PreCon_C_AGPH_HR75	PreCon_C_T1R	PreCon_C_SP	PreCon_C_DP
110	76	9	6	63	24	18	146	132	93
86	63	5	1	48	15	2	172	104	71
84	68	4	2	64	10	5	187	106	69
82	22	-8	-11	60	-21	-29	203	105	68
76	55	2	-3	43	6	-10	168	93	62
96	65	6	6	75	18	18	140	115	81
102	104	21	15	58	42	34	135	132	82
89	81	8	4	53	23	12	162	110	76
93	69	7	1	43	19	4	155	115	80
82	31	-3	-3	75	-16	-16	147	92	73
87	51	0	-4	46	-2	-16	149	100	76
97	82	11	8	63	28	22	143	119	79
98	60	3	1	61	10	4	173	114	85
97	53	0	-5	50	-1	-12	197	119	78
82	73	6	9999	40	19	9999	180	102	68
92	87	10	5	51	30	18	154	113	78
84	62	3	0	48	13	0	153	96	72
92	55	-1	-5	53	-3	-13	205	111	76
77	61	2	-2	47	7	-6	201	96	64
93	87	6	4	62	22	16	181	109	81
96	86	13	4	41	28	12	161	123	77
92	68	6	2	52	19	8	154	108	77
79	52	2	-3	47	5	-8	9999	98	65
90	67	6	1	50	14	2	185	113	69
80	46	1	0	72	2	0	161	97	65
80	45	0	-2	65	-1	-6	172	94	67
87	44	-2	-5	55	-5	-15	218	105	72
93	75	6	2	51	17	5	190	111	79
84	80	7	2	44	24	9	147	101	72
93	86	12	5	45	30	16	153	117	77
81	64	1	0	70	4	1	186	98	67
105	76	6	5	66	17	13	172	126	89
98	84	9	5	56	28	19	155	114	84
86	61	5	1	53	13	2	183	108	69
103	81	8	8	73	21	20	149	125	86
89	46	-1	-4	53	-3	-14	151	107	74

PreCon_C_MEANP	PreCon_C_AI	PostCon_Operator Index	PostCon_P_SP	PostCon_P_DP	PostCon_P_MEANP	PostCon_P_AI	PostCon_C_AP	PostCon_C_AP_HR75	PostCon_HR	PostCon_C_AGPH
110	131	100	151	96	116	86	14	9	57	31
86	117	92	121	65	84	65	7	2	50	18
84	111	100	115	72	85	60	3	0	57	9
82	79	98	123	66	78	9999	-6	-8	58	-17
76	106	100	104	61	73	49	-2	-6	43	-6
96	122	100	150	88	109	74	12	9	66	25
102	172	98	143	84	108	94	22	14	52	41
89	130	91	131	82	98	78	8	4	52	22
93	124	100	128	79	94	81	10	3	41	26
82	84	100	104	76	84	39	-1	-1	73	-7
87	98	95	115	75	86	54	0	-2	51	2
97	139	99	128	85	101	84	10	8	62	30
98	111	96	121	84	97	66	4	2	58	16
97	99	100	134	74	92	51	1	-4	48	2
82	123	91	115	73	86	68	5	0	41	16
92	143	100	121	82	96	87	11	6	50	32
84	115	97	113	75	87	74	5	1	45	19
92	97	97	130	79	94	51	0	-4	52	-1
77	108	100	104	64	77	60	3	-1	47	11
93	128	100	117	80	94	88	9	6	58	29
96	140	95	124	76	91	81	15	7	44	37
92	124	100	117	78	92	64	4	1	50	16
79	105	100	115	68	82	55	1	-3	45	4
90	117	98	128	78	92	60	4	-1	48	11
80	102	97	117	74	87	44	0	-1	62	0
80	99	100	105	61	73	42	0	-3	56	-2
87	95	99	121	71	86	48	-3	-6	50	-8
93	121	100	124	78	92	62	4	0	47	13
84	132	99	110	72	85	81	7	2	43	24
93	143	100	130	83	99	92	14	6	43	33
81	104	100	117	69	85	68	3	0	59	8
105	120	100	145	94	110	71	6	3	60	17
98	139	98	131	85	102	83	10	6	59	26
86	114	100	118	62	80	56	3	0	53	9
103	127	100	127	79	94	74	9	6	62	23
89	97	97	136	79	96	57	2	-1	53	7

PostCon_C_AGPH_HR75	PostCon_C_T1R	PostCon_C_SP	PostCon_C_DP	PostCon_C_MEANP	PostCon_C_AI
23	141	143	97	116	146
6	175	105	66	84	122
1	170	102	73	85	110
-25	159	99	66	78	83
-21	188	87	61	73	94
20	134	136	89	109	133
30	134	140	86	108	170
10	162	121	83	98	128
10	150	118	80	94	136
-8	147	92	77	84	93
-10	154	99	76	86	102
24	143	121	86	101	143
8	162	111	85	97	118
-11	186	112	75	92	102
-1	189	105	74	86	119
20	147	116	83	96	147
4	165	103	75	87	123
-12	164	109	80	94	99
-2	184	93	64	77	113
21	170	112	81	94	140
23	180	116	76	91	159
4	164	106	79	92	119
-10	155	97	69	82	104
-2	167	112	78	92	112
-6	159	100	75	87	100
-11	170	88	62	73	98
-21	198	103	72	86	92
-1	179	111	78	92	115
9	147	101	72	85	132
17	152	125	84	99	149
0	188	104	70	85	108
10	168	132	95	110	121
18	158	123	86	102	136
-1	161	100	63	80	110
17	144	116	79	94	131
-4	147	114	80	96	107

Subject	Group	BodySurfaceArea Dubois Formula (m2)	PreEx_SV (ml)	PreEX-SV_Index (ml/beat)/m2)	PreEx_EDV (ml)
2	3	1.92	123	64	188
3	1	1.92	111	58	193
4	3	2.23	110	49	188
5	1	1.97	70	35	115
6	1	1.82	93	51	177
7	3	1.79	97	54	141
9	2	2.07	79	38	137
10	3	1.96	95	49	132
11	1	1.66	59	35	98
12	1	1.81	98	54	174
14	2	2.01	76	38	111
15	1	2.17	89	41	143
16	2	2.05	102	50	173
17	3	2.01	94	47	152
20	2	1.70	76	45	135
22	1	1.97	63	32	109
23	3	1.86	86	46	152
24	3	2.01	102	51	199
26	2	1.87	102	54	179
27	2	1.88	87	46	158
28	2	1.95	117	60	185
29	1	1.91	90	47	158
30	1	1.85	93	50	144
31	1	1.92	88	46	146
32	1	1.90	81	43	137
34	2	2.04	76	37	161
36	3	1.89	62	33	100
37	2	2.09	83	40	137
38	2	2.00	124	62	179
40	2	1.98	117	59	187
41	2	1.89	81	43	131
43	1	1.94	99	51	176

PreEX_EDV_Index	PreEx_ESV (ml)	PreEX_ESV_Index	PreEx_HR (bpm)	PreEx_CO (l/min/100)	PreEX_CO_Index	PreEx_EF (%)
98	65	34	59	7.2	3.8	65
101	81	42	51	5.7	3.0	58
84	78	35	67	7.3	3.3	59
58	46	23	66	4.6	2.3	61
97	84	46	47	4.4	2.4	52
79	44	24	68	6.6	3.7	69
66	57	27	56	4.4	2.1	59
67	37	19	46	4.4	2.2	72
59	39	24	76	4.5	2.7	60
96	77	43	48	4.7	2.6	56
55	35	17	59	4.5	2.2	68
66	54	25	45	4.0	1.9	62
85	71	35	43	4.4	2.1	59
76	59	29	49	4.6	2.3	61
79	59	35	48	3.7	2.2	57
55	46	23	63	3.9	2.0	58
82	65	35	46	4.0	2.1	57
99	98	49	56	5.7	2.8	51
96	77	41	47	4.8	2.6	57
84	71	38	48	4.2	2.2	55
95	68	35	49	5.7	2.9	63
83	68	36	56	5.0	2.6	57
78	50	27	64	6.0	3.2	65
76	59	31	60	5.3	2.7	59
72	55	29	56	4.6	2.4	60
79	86	42	45	3.4	1.7	47
53	38	20	52	3.2	1.7	62
65	53	26	79	6.6	3.2	61
89	55	28	60	7.4	3.7	69
94	71	36	57	6.7	3.4	63
69	50	26	62	5.0	2.7	64
90	77	39	58	5.7	3.0	57

PreEx_FS (%)	PostEx_SV (ml)	PostEx_SV_Index	PostEx_HR (bpm)	PostEx_CO (l/min)	PostEx_CO_Index	PostEx_EF (%)
37	143	75	65	9.3	4.8	69
31	84	44	89	7.5	3.9	58
32	133	60	85	11.3	5.1	68
32	74	38	77	5.7	2.9	62
28	83	46	70	5.8	3.2	56
39	97	54	98	9.5	5.3	71
31	100	48	77	7.7	3.7	60
41	80	41	52	4.1	2.1	67
32	76	46	94	7.1	4.3	67
29	89	49	94	8.4	4.6	58
39	70	35	78	5.4	2.7	66
34	94	43	92	8.7	4.0	61
32	125	61	56	7.0	3.4	69
33	104	51	83	8.6	4.3	61
30	78	46	56	4.3	2.6	59
31	58	30	93	5.4	2.8	60
30	87	47	51	4.4	2.4	58
27	70	35	74	5.2	2.6	59
30	102	54	50	5.1	2.7	60
29	83	44	60	5.0	2.7	55
35	99	51	61	6.0	3.1	61
30	72	38	67	4.8	2.5	54
36	91	49	108	9.9	5.3	68
32	78	40	88	6.8	3.6	60
32	93	49	77	7.1	3.8	58
24	80	39	69	5.5	2.7	50
34	61	32	53	3.2	1.7	58
33	82	39	86	7.0	3.4	61
39	96	48	93	9.0	4.5	64
35	134	68	60	8.0	4.1	75
36	92	49	87	8.0	4.2	65
31	87	45	77	6.7	3.5	55

PostEx_FS (%)	PreCON_SV (ml)	PreCON_SV_Index	PreCON_HR (bpm)	PreCON_CO (l/min/100)	PreCON_CO_Index	PreCON_EF (%)
40	147	76	60	8.8	4.6	72
31	76	40	47	3.6	1.9	58
39	88	40	56	4.9	2.2	60
34	70	36	66	4.6	2.3	59
30	85	47	46	3.9	2.1	53
40	104	58	72	7.5	4.2	62
32	96	46	54	5.2	2.5	68
37	90	46	42	3.8	1.9	67
37	70	42	69	4.8	2.9	56
31	101	56	49	4.9	2.7	65
36	84	42	65	5.5	2.7	63
33	87	40	45	3.9	1.8	58
50	114	55	39	4.4	2.2	65
33	87	43	50	4.4	2.2	55
31	118	70	47	5.6	3.3	62
32	68	35	51	3.5	1.8	62
31	74	40	48	3.6	1.9	54
31	99	49	59	5.8	2.9	60
33	114	61	41	4.7	2.5	54
29	80	42	49	3.9	2.1	57
33	106	54	49	5.2	2.7	66
28	80	42	52	4.1	2.2	50
38	76	41	62	4.7	2.5	58
32	89	46	60	5.3	2.8	52
31	86	45	62	5.3	2.8	53
26	93	45	42	3.9	1.9	61
30	63	33	45	2.9	1.5	61
33	87	42	68	5.9	2.8	57
35	114	57	65	7.4	3.7	64
37	119	60	52	6.2	3.1	70
36	86	46	70	6.0	3.2	65
29	105	54	58	6.1	3.1	55

PreCON_ FS (%)	PostCON_SV (ml)	PostCON_SV_ Index	PostCON_HR (bpm)	PostCON_CO (l/min)	PostCON_CO_ Index	PostCON_E F (%)	PostCO N_FS (%)
42	123	64	59	7.3	3.8	66	37
31	90	47	47	4.2	2.2	57	30
33	122	55	53	6.5	2.9	67	38
31	103	52	61	6.3	3.2	63	35
28	87	48	46	4.0	2.2	57	30
34	93	52	69	6.4	3.6	61	33
38	98	47	52	5.1	2.5	61	33
37	88	45	40	3.5	1.8	64	35
29	80	48	71	5.7	3.4	63	34
36	86	47	49	4.2	2.3	61	33
35	85	42	56	4.8	2.4	62	35
32	93	43	49	4.6	2.1	57	30
36	114	56	38	4.3	2.1	69	39
29	100	50	47	4.7	2.3	60	33
34	118	69	45	5.3	3.1	62	34
34	64	32	51	3.2	1.7	59	31
29	62	33	44	2.7	1.5	52	27
32	88	44	57	5.0	2.5	52	27
28	102	55	40	4.1	2.2	102	33
30	84	45	44	3.7	2.0	67	37
37	102	52	46	4.7	2.4	60	32
26	87	46	49	4.3	2.2	56	29
31	74	40	59	4.4	2.4	57	30
27	96	50	56	5.4	2.8	57	31
28	86	45	53	4.6	2.4	59	32
33	85	42	44	3.7	1.8	59	31
33	74	39	41	3.0	1.6	73	42
30	77	37	54	4.2	2.0	56	29
35	113	56	65	7.3	3.7	61	33
40	128	64	50	6.4	3.2	71	41
36	89	47	60	5.3	2.8	64	36
29	109	56	55	6.0	3.1	63	33

Subject	EX (FBF)	1	2	3	4	5	6	Avg
2	Pre	3.5	3.87	4.51	3.2	4.17	3.69	3.82
	Post	4.23	3.57	3.25	3.62	3.47	2.96	3.52
3	Pre	2.79	2.48	2.7	2.52	2.3	1.03	2.30
	Post	6.64	6.38	6.29	6.18	6.01	6.35	6.31
4	Pre	3.28	3.36	3.38	2.7	3.52	2.45	3.12
	Post	6.56	6.27	6.64	6.72	8.37	6.72	6.88
5	Pre	2.64	2.72	3.12	3.24	3.83	3.54	3.18
	Post	3.92	4.41	4.81	4.97	4.85	5.43	4.73
6	Pre	3.6	3.04	3.36	2.87	3.42	2.96	3.21
	Post	5.95	5.61	6.16	7.38	7.18	6.16	6.41
7	Pre	2.35	1.68	1.69	1.6	2.08	1.9	1.88
	Post	4.93	4.17	4.41	4.19	4.32	5.01	4.51
8	Pre	3.85	3.45	3.32	2.33	3.34	3.15	3.24
	Post	7.36	7.44	7.12	7.67	7.02	7.12	7.29
9	Pre	3.73	3.28	4.03	4.57	4.33	3.96	3.98
	Post	8.07	7.14	6.62	7.71	7.07	6.94	7.26
10	Pre	2.65	2.46	2.63	2.58	2.5	2.52	2.56
	Post	4.43	5.17	4.46	5.34	5.14	5.2	4.96
11	Pre	1.35	1.34	1.19	1.82	2.38	1.47	1.59
	Post	7.06	5.62	4.33	4.91	4.98	5.68	5.43
12	Pre	0.48	1.9	1.47	1.29	1.16	1.31	1.27
	Post	4.71	4.97	4.76	4.68	5.1	4.79	4.84
13	Pre	2.88	1.98	2.24	2.09	2.23	2.3	2.29
	Post	5.57	4.85	5	5.82	6	5.58	5.47
14	Pre	1.86	1.16	1.73	2.22	1.63		1.72
	Post	4.01	3.64	3.46	4.03	4.08	2.48	3.62
15	Pre	1.89	1.94	1.94	1.9	2.31	2.15	2.02
	Post	5.95	6.96	7.09	6.92	6.88	6.89	6.78
16	Pre	1.81	1.34	1.64	1.6	2.9	1.9	1.87
	Post	4.16	3.65	4.12	4.98	4.4	4.46	4.30
17	Pre	2.45	2	2.24	2.24	2.22	2.23	2.23
	Post	8.14	6.24	5.08	6.69	5.92	6.27	6.39
18	Pre							#DIV/0!
	Post							#DIV/0!
19	Pre							#DIV/0!
	Post							#DIV/0!
20	Pre	2.33	1.85	1.88	1.87	1.6	2.73	2.04
	Post	3.1	2.78	2.46	2.81	3.52	2.82	2.92
21	Pre							#DIV/0!
	Post							#DIV/0!
22	Pre	2.13	2.26	2.73	2.52	2.26	2.53	2.41
	Post	5.79	5.68	6.15	6.52	4.87	4.33	5.56
23	Pre	1.86	1.52	2.02	2.08	2.18	1.29	1.83
	Post	1.49	2.35	1.87	1.94	2.1	1.84	1.93
24	Pre	0.82	0.92	1.52	1.09	1.58	0.91	1.14
	Post	2.43	3.45	2.83	2.99	3.16	3.06	2.99
25	Pre							#DIV/0!
	Post							#DIV/0!
26	Pre	2.89	3.1	3.04	2.68	2.97	3	2.95
	Post	2.36	3.04	2.81	2.43	2.44	2.41	2.58
27	Pre	3.52	3.49	3.42	3.32	2.64	3.62	3.34
	Post	4.97	4.94	4.95	5.33	4.8	5.55	5.09
28	Pre	1.81	2.6	2.01	1.96	2.28	2.22	2.15
	Post	5.61	5.67	5.65	5.38	5.61	5.12	5.51
29	Pre	3.82	3.56	3.75	3.73	3.4	3.26	3.59
	Post	5.46	5	5.33	4.79	4.98	4.79	5.06
30	Pre	2.89	2.65	3.26	2.78	3	3.2	2.96
	Post	6.18	6.76	5.75	5.76	5.65	6.27	6.06
31	Pre	2.73	3.26	3.38	3.06	3.17	3.62	3.20
	Post	5.92	6.76	6.52	6.96	6.8	6.96	6.65
32	Pre	2.65	2.38	2.43	2.12	2.8	2.3	2.45

	Post	6.27	6.43	6.46	6.81	6.55	7.01	6.59
33	Pre	2.87	1.92	0.72		1.78	2.34	1.93
	Post	1.05	2.14	1.67	2.13	1.93	1.3	1.70
34	Pre	2.03	1.94	1.11	2.01	1.43	1.56	1.68
	Post	4.21	4.08	3.94	3.31	3.58	3.46	3.76
35	Pre							#DIV/0!
	Post							#DIV/0!
36	Pre	1.93	2.53	2.19	2.06	2.72	2.6	2.34
	Post	2.16	2.52	2.9	2.43	2.59	2.92	2.59
37	Pre	6.11	5.36	6.33	6.42	6.68	6.54	6.24
	Post	5.61	5.75	6.68	6.04	6.22	7.01	6.22
38	Pre	2.92	2.92	3.45	3.5	3.25	3.27	3.22
	Post	7.04	6.24	6.27	6.6	7.19	7.6	6.82
39	Pre	2.57	2.96	2.8	2.57	2.39	2.75	2.67
	Post	5.54	5.34	5.7	4.62	5.58	5.73	5.42
40	Pre	11.45	11.92	13.06	13.65	13.56	13.57	12.87
	Post	9.41	10.32	10.91	10.13	10.24	11.22	10.37
41	Pre	3.82	4.17	4.02	4.28	5.09	3.84	4.20
	Post	2.77	3.04	3.36	3	2.84	3.56	3.10
42	Pre							#DIV/0!
	Post							#DIV/0!
43	Pre	2.6	2.17	2.46	2.02	2.55	2.23	2.34
	Post	5.55	5.26	5.7	5.35	5.01	5.67	5.42

CON (FBF)	1	2	3	4	5	6	Avg
Pre	3.08	3.16	3.64	3.84	3.85	4.2	3.63
Post	2.92	2.82	2.65	2.71	2.35	2.24	2.62
Pre	4.6	4.33	4.09	4.36	3.88	4.32	4.26
Post	3.32	2.49	3.18	3.46	2.26	2.53	2.87
Pre	2.19	3.4	4.13	3.26	2.41	3.04	3.07
Post	3.52	4.07	2.05	2.45	2.24	1.39	2.62
Pre	3.56	4.09	3.76	3.31	3.52	4.28	3.75
Post	3.16	3.27	2.7	2.69	2.31	3.32	2.91
Pre	2.96	2.27	2.58	1.93	2.07	2.26	2.35
Post	2.08	2.16	2.02	2.59	2.25	2.71	2.30
Pre	2.83	1.8	0.84	1.29	1.97	1.71	1.74
Post	1.85	1.52	1.67	1.7	1.87	1.53	1.69
Pre	2.11	2.6	2.8	2.06	2.68	2.55	2.47
Post	2.59	2.15	1.87	2.35	2.54	2.38	2.31
Pre	4.04	3.62	2.69	3.99	3.4	3.41	3.53
Post	2.63	2.29	1.61	2.56	2.34	1.8	2.21
Pre	3.34	3.22	2.65	3.16	3.3	2.5	3.03
Post	2.4	2.64	2.89	2.31	1.77	2.11	2.35
Pre	1.39	1.48	1.11	1.51	1.27	2.54	1.55
Post	1.06	0.84	1.5	1.64	1.17	0.72	1.16
Pre	1.54	0.98	1	0.61	1.33	1.51	1.16
Post	2.54	1.86	1.2	1.13	2.24	2.1	1.85
Pre	3.2	2.97	3.24	2.61	2.83	3.54	3.07
Post	2.82	2.7	2.28	2.41	2.41	2.37	2.50
Pre	2.57	1.96	1.83	1.78	2.24	1.59	2.00
Post	1.71	0.86	1.66	0.85	0.87	1.12	1.18
Pre	3.1	2.66	2.14	2.32	2.48	2.87	2.60
Post	1.85	2.02	1.94	2.37	1.94	2.53	2.11
Pre	3.1	2.71	3.28	2.85	2.3	2.48	2.79
Post	2.61	2.28	2.24	2.05	2.49	2.92	2.43
Pre	1.8	1.97	2.1	2.59	2.28	3.26	2.33
Post	2.32	1.86	1.31	1.52	2.1	2.05	1.86
Pre							#DIV/0!
Post							#DIV/0!
Pre							#DIV/0!
Post							#DIV/0!
Pre	1.52	2.19	1.7	2.2	1.46	1.29	1.73
Post	1.9	1.74	0.96	1.69	1.99	1.19	1.58
Pre							#DIV/0!
Post							#DIV/0!
Pre	1.85	1.75	1.35	1.62	2.49	1.68	1.79
Post	2.3	1.77	2.02	1.62	2.04	2.07	1.97
Pre	1.4	1.41	1.65	1.7	1.47	1.33	1.49
Post	1.33	1.55	0.93	1.68	1.87	1.67	1.51
Pre	2.07	1.86	1.57	1.75	2.14	2.31	1.95
Post	1	1.92	1.68	1.44	1.21	1.24	1.42
Pre							#DIV/0!
Post							#DIV/0!
Pre	3.41	3.12	2.66	2.83	3.57	3.12	3.12
Post	2.11	2.3	2.44	2.06	1.59	2.11	2.10
Pre	2.14	2.5	3.09	2.57	2.24	3.11	2.61
Post	3.1	2.87	2.75	1.76	1.48	2.41	2.40
Pre	2.28	3.04	3.32	2.94	2.64	2.22	2.74
Post	3.29	2.04	2.36	3.02	2.54	2.55	2.63
Pre	4.25	4.15	3.66	4.18	3.32	3.57	3.86
Post	3.44	3.52	2.78	3.06	3.27	3.03	3.18
Pre	3.52	3.12	2.87	3.72	3.2	2.7	3.19
Post	1.8	1.91	2.58	2.17	1.86	2.15	2.08
Pre	2.48	4.19	2.71	3.34	2.53	3.96	3.20
Post	3.26	3.36	2.9	3.57	3.24	3.36	3.28
Pre	5.33	6.27	5.64	5.85	5.55	5.26	5.65
Post	1.83	2.75	2.08	2.17	1.97	2.58	2.23
Pre	2.15	2.19	1.57	0.62	2.51	2.61	1.94

Post	1.92	1.4	4.31	1.9	1.93	1.77	2.21
Pre	1.49	1.3	1.26	1.28	1.2	1.03	1.26
Post	2.83	1.71	2.17	1.4	1.23	1.77	1.85
Pre							#DIV/0!
Post							#DIV/0!
Pre	2.22	1.55	1.57	1.93	1.57	2.1	1.82
Post	1.65	1.66	2.28	1.31	1.62	1.71	1.71
Pre	3.22	2.94	3.24	3.46	3.98	3.77	3.44
Post	3.08	3.02	3	2.75	2.75	2.75	2.89
Pre	4.39	3.78	3.79	4.01	3.6	4.05	3.94
Post	3.85	3.1	2.57	3.2	3.38	3.15	3.21
Pre	3.38	2.8	2.46	2.34	2.07	2.22	2.55
Post	3.56	3	3.64	3.34	2.94	2.56	3.17
Pre	7.93	8.87	5.68	7.39	7.8	7.71	7.56
Post	3.68	3.4	3.32	2.66	3.55	4.62	3.54
Pre	2.45	2.46	2.08	2.71	2.78	3.31	2.63
Post	2.09	2.63	2.75	2.6	2.31	2.38	2.46
Pre							#DIV/0!
Post							#DIV/0!
Pre	2.78	2.78	2.55	2.46	3.38	2.65	2.77
Post	2.8	2.34	3.1	3.25	2.48	2.89	2.81

Subject	Group	Pre_EX_FBF	MAP	Pre_EX_FBF_VC	Pre_CON_FBF	MAP
2	3	3.82	105	36.41	3.63	110
3	1	2.30	85	27.10	4.26	86
4	3	3.12	87	35.80	3.07	84
5	1	3.18	86	37.00	3.75	82
6	1	3.21	76	42.21	2.35	76
7	3	1.88	106	17.77	1.74	96
8	3	3.24	102	31.76	2.47	102
9	2	3.98	90	44.26	3.53	89
10	3	2.56	83	30.80	3.03	93
11	1	1.59	85	18.73	1.55	82
12	1	1.27	95	13.35	1.16	87
13	3	2.29	103	22.20	3.07	97
14	2	1.72	93	18.49	2.00	98
15	1	2.02	91	22.22	2.60	97
16	2	1.87	85	21.94	2.79	82
17	3	2.23	93	23.98	2.33	92
20	2	2.04	83	24.62	1.73	84
22	1	2.41	88	27.33	1.79	92
23	3	1.83	74	24.66	1.49	77
24	3	1.14	95	12.00	1.95	93
26	2	2.95	90	32.74	3.12	96
27	2	3.34	88	37.90	2.61	92
28	2	2.15	90	23.85	2.74	79
29	1	3.59	95	37.75	3.86	90
30	1	2.96	86	34.46	3.19	80
31	1	3.20	82	39.07	3.20	80
32	1	2.45	85	28.78	5.65	87
33	2	1.93	93	20.71	1.94	93
34	2	1.68	84	20.00	1.26	84
36	3	2.34	88	26.57	1.82	93
37	2	6.24	88	70.91	3.44	81
38	2	3.22	98	32.84	3.94	105
39	2	2.67	102	26.21	2.55	98
40	2	12.87	84	153.19	7.56	86
41	2	4.20	99	42.46	2.63	103
43	1	2.34	89	26.27	2.77	89

Pre_CON_FBF_VC	Post_EX_FBF	MAP	Post_EX_FBF_VC	Post_CON_FBF	MAP	Post_CON_FBF_VC
32.98	3.52	106	33.18	2.62	116	22.54
49.57	6.31	88	71.69	2.87	84	34.21
36.57	6.88	86	80.00	2.62	85	30.82
45.77	4.73	79	59.89	2.91	78	37.29
30.86	6.41	79	81.10	2.30	73	31.53
18.13	4.51	87	51.78	1.69	109	15.50
24.18	7.29	103	70.76	2.31	108	21.42
39.61	7.26	86	84.40	2.21	98	22.50
32.56	4.96	86	57.64	2.35	84	28.02
18.90	5.43	75	72.40	1.16	94	12.29
13.35	4.84	106	45.61	1.85	86	21.45
31.60	5.47	99	55.25	2.50	101	24.74
20.36	3.62	94	38.48	1.18	97	12.15
26.75	6.78	81	83.72	2.11	92	22.92
33.98	4.30	80	53.69	2.43	86	28.28
25.36	6.39	89	71.80	1.86	96	19.38
20.56	2.92	86	33.90	1.58	87	18.14
19.46	5.56	83	66.95	1.97	94	20.96
19.39	1.93	78	24.76	1.51	77	19.55
20.97	2.99	92	32.46	1.42	94	15.05
32.48	2.58	82	31.48	2.10	91	23.10
28.35	5.09	84	60.60	2.40	92	26.03
34.68	5.51	83	66.35	2.63	82	32.11
42.83	5.06	98	51.62	3.18	92	34.60
39.85	6.06	78	77.71	2.08	87	23.89
40.02	6.65	78	85.30	3.28	73	44.95
64.94	6.59	80	82.35	2.23	86	25.93
20.88	1.70	86	19.81	2.21	92	23.97
15.00	3.76	74	50.86	1.85	85	21.78
19.61	2.59	91	28.42	1.71	99	17.22
42.41	6.22	86	72.31	2.89	85	34.02
37.49	6.82	92	74.17	3.21	110	29.17
25.97	5.42	97	55.86	3.17	102	31.11
87.95	10.37	87	119.21	3.54	80	44.23
25.55	3.10	95	32.58	2.46	94	26.17
31.09	5.42	93	58.32	2.81	96	29.27

Group	PreEX_R (PWV)	PreEX_F (PWV)	PostEX_R (PWV)	PostEX_F (PWV)	PreCON_R (PWV)	PreCON_F (PWV)	PostCON_R (PWV)	PostCON _F (PWV)
1	8.9	6.1	7.4	7.2	7.2	7.2	7.7	7.1
3	10	8.7	8.8	9.4	8.8	8.7	9.1	8.3
1	8.5	6.8	7.5	8.5	7.3	6.2	6.9	6.5
3	7.4	8.1	7	8.3	7.1	7.2	7.4	7.9
1	7.8	5.7	8.4	5.5	7.4	6.1	8.9	5.7
1	7.6	5.4	7	5.5	7.2	4.5	8.1	5.7
3	8.3	10.6	7.9	11.8	8.6	9.4	9.3	8
3	4.9	7.8	7.5	8	6.2	7.9	8.4	8.1
2	7.2	7.3	6.8	6.7	8.4	7.1	8.4	7.6
3	7.1	6.1	6.5	5.5	9.5	7.2	8.5	5.4
1	7.8	6.7	6.4	6.4	7.1	6.1	7	5.3
1	7.8	6	6.5	7.5	7.6	5.8	7	5.6
3	8.6	10.7	9	10	8	10	8.5	10.4
2	7.8	7.1	9.6	8.3	7.5	7.3	7.6	7.2
1	8.1	6	8	5.8	7.3	5.3	9.2	5.6
2	7	5.2	6.3	5.4	6.9	5.5	6.7	5.8
3	8.4	7.5	7.8	7.3	9.8	8.4	8.3	6.4
2	7.3	5.2	8.6	5.7	7.1	6.1	6.7	6.2
1	7.9	6.6	7.2	7.4	9.4	6.3	8.9	5.9
3	9.7	6.9	8.6	8.3	7.6	8	8.1	7.3
3	9	8.2	10.7	7.5	10.5	8.3	9.1	8.9
2	6.3	6	7	5.9	6.6	6.3	7.6	6.8
2	6.9	6.4	6.5	5.6	8.7	6.1	6.8	8.1
2	6.5	6.4	6.7	6.5	7.6	5.9	8.9	6.6
1	7.4	5.8	7.9	5.5	6.9	5.5	6.6	5.8
1	7.6	6.6	6.2	7.8	6.3	6.8	6.9	6.5
1	6.5	4.5	6.3	5.4	6.3	5.4	6.2	5
1	7.4	5.4	6.6	5.5	9.3	5.7	10.4	5.5
2	7.7	7	7.3	6.7	7.9	7.1	8.9	6.9
2	7.4	5.8	9.5	5.6	7.5	5	8.6	5.3
3	8	8.1	8	7	8.3	7.9	8.6	7.8
2.0	7.4	6.8	6.0	8.7	7.7	7.1	8.3	6.7
2	7.4	7.2	6.6	7.1	8.8	9.2	8.3	7.1
2	9.5	7.5	8.7	7.8	6.3	7.6	8.1	8.4
2	7.7	6.4	7.3	6.7	7.3	6.9	8.1	5.9
2.0	8.5	7.8	9.2	9.7	7.7	9.4	8.4	8.7
1.0	8.6	6.4	7.3	7.4	7.5	6.5	8.7	6.4