8-2022

Body Composition, Muscular Strength, Arterial Stiffness, and Hemodynamics Responses to Various Training Protocols in Young Males

Jorge Bejar
The University of Texas Rio Grande Valley

BODY COMPOSITION, MUSCULAR STRENGTH, ARTERIAL STIFFNESS, AND HEMODYNAMICS RESPONSES TO VARIOUS TRAINING PROTOCOLS IN YOUNG MALES

A Thesis

by

JORGE BEJAR

Submitted in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

Major Subject: Exercise Science

The University of Texas Rio Grande Valley

August 2022

BODY COMPOSITION, MUSCULAR STRENGTH, ARTERIAL STIFFNESS, AND HEMODYNAMICS RESPONSES TO VARIOUS TRAINING PROTOCOLS IN YOUNG MALES

A Thesis
by
JORGE BEJAR

COMMITTEE MEMBERS

Dr. Murat Karabulut
Chair of Committee

Dr. Ulku Karabulut
Committee Member

Dr. Samuel Buchanan
Committee Member

August 2022

ABSTRACT

Bejar, Jorge, Body Composition, Muscular Strength, Arterial Stiffness, and Hemodynamics Responses to Various Training Protocols in Young Males. Master of Science (MS), August, 2022, 148 pp., 2 tables, 90 figures, references, 120 titles.

PURPOSE: The purpose of this study was to compare the effects of 8 weeks performing various resistance training protocols with and without blood flow restriction (BFR) on muscular strength, body composition, arterial elasticity, and hemodynamics responses in young males.

RESULTS: Significant time*condition interactions occurred in HR period ($p < 0.05$), HDI SBP ($p < 0.05$), HDI MAP ($p < 0.05$), and SV ($p < 0.05$). Trends for time*condition interactions were found in HDI DBP ($p = 0.054$), HDI HR ($p = 0.051$), and HDI SVR ($p = 0.085$). Significant time main effects occurred in all strength measures ($p < 0.05$). Significant condition main effects occurred in Aortic DBP ($p < 0.05$), Brachial DBP ($p < 0.05$), and LAE ($p < 0.05$). Total lean mass significantly increased from baseline the HI condition only ($p < 0.05$).

CONCLUSION: Significant improvements in lean mass were seen following the HI and BFR protocols. However, decreases in LAE were found following the HI protocol only. It appears that performing aerobic exercise after resistance training can negatively affect muscle growth. However, only 15 min of moderate-intensity aerobic training can improve hemodynamics in young, healthy males. Improvements in SBP, DBP, SVR, MAP, HR and SV were seen following the HI+AE protocol.

KEYWORDS: Blood flow restriction, pulse wave velocity, arterial elasticity

DEDICATION

The completion of this thesis study would not have been possible without the support of my parents, Jorge Bejar and Esmeralda Mendez. I would not be here without their unconditional support throughout my entire college journey. I would also like to dedicate this to my amazing girlfriend, Paola Vidal. She has supported me emotionally and intellectually throughout every step, and I know that I would not be here if it wasn't for her. My parents and girlfriend always pushed me to be the best version of myself, therefore I dedicate this accomplishment to them

ACKNOWLEDGMENTS

I am extremely grateful for everyone who has been part of this process. I would like to thank all members of my committee for all their guidance during these two years. Thank you Dr. Murat Karabulut, Dr. Ulku Karabulut, and Dr. Samuel Buchanan for being such great mentors, I could not have asked for a better thesis committee.

I also want to give a special thanks to my committee chair, Dr. K. Thanks to his support, I was able to join the Master's program two years ago. Since then, he taught me more than I could have imagined when I joined the program. He has been the mentor that I hoped to have someday, and thanks to him, I was able to finish my thesis on time. Even on vacation, he always took the time to mentor me and guide me in any way possible. His work ethic is beyond anything that I have ever seen, which is why he is one of the best in the field. I will be forever grateful to Dr. K for all his guidance and support throughout this process.

I would also like to thank the people that helped me throughout the study. Especially Antonio Vargas for helping with data collection, data entry, and paperwork; Alexis Lopez for helping with data collection even when he was also busy with his study. I am very thankful for both of you, and I know that you made my graduate journey much more enjoyable.

Lastly, I would like to thank all my participants for completing the study. Thank you for all your time and for trusting my advice when exercising.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

Exercise has been proven to be extremely beneficial when performed within the recommended guidelines (Nystoriak et al., 2018; Vina et al., 2012; Agarwal., 2012). Performing any kind of exercise has been shown to improve many aspects of health, including: a reduction in risk for diabetes, coronary heart diseases, myocardial infarctions, and even many types of cancer (Penedo, 2005). For this reason, different exercise methods have been recommended to improve quality of life in many populations.

Even with all the health improvements that exercise provides, there are some negative effects that come with some training modalities. High-intensity resistance training (HI-RT) has been shown to have many positive effects on health, but this training mode has also been shown to elicit potential negative health effects (Miyachi et al., 2004). In order to continue overloading a muscle, training load has to be relatively high, therefore proper breathing becomes extremely important. One of the most used respiration techniques is the Valsalva maneuver (VM), which is the forced exhalation against a closed glottis. The VM has been shown to be effective at increasing intraabdominal pressure, creating a more stable and compact spine which allows a person to lift heavier loads. (Heffernan, 2007). The increases in intraabdominal pressure provoke an increase in blood pressure, which could be the most important factor in causing a decreased elasticity of the arteries (Ozaki et al., 2013).

Although training with high intensities has been shown to be ideal for muscle hypertrophy, an increase in arterial stiffness can become a negative factor on long-term health. Many studies have shown an increase in arterial stiffness following chronic HI-RT (Ozaki et al., 2013; Cortez-Cooper et al., 2005; Kawano et al., 2006). This stiffness is believed to be caused by the immediate increase in blood pressure when lifting (Ozaki, 2013). These acute intermittent elevations in blood pressure could be altering arterial structure, increasing the stiffening. In addition, another possible explanation could be that the arterial load-bearing properties of collagen and elastin can be altered with the increase in blood pressure (Ozaki, 2013). HI-RT exercises are necessary to improve muscle mass and strength, but decreased arterial elasticity associated with this training modality is a concerning health issue and needs to be addressed (Ozaki et al., 2013).

Blood flow restriction (BFR) training is an alternative mode of training which can have many positive effects on health even when exercising at lower intensities (Ozaki et al., 2013; Karabulut et al., 2010; Abe et al., 2010). This type of training approach uses pressurized cuffs to partially restrict venous blood flow from the working muscles. This restriction causes an accumulation of metabolites in the working muscles, which results in similar hypertrophy and strength adaptations associated with traditional HI-RT, even when performed at lower intensities (Spranger et al., 2015). Since BFR does not require high loads to challenge the muscles, blood pressure can be more stable throughout the exercise session. Consequently, this low-intensity training method can be one of the keys for the conservation of arterial elasticity.

Another training method that could prevent the decrease in arterial elasticity is aerobic training. Research shows that aerobic training significantly increases arterial elasticity in the long term (Tanaka, 2000). Kawano et al. (2006) concluded that with only 30 min of aerobic training three times per week, arterial stiffness could be attenuated even if HI-RT is being performed simultaneously. This study will provide further evidence to see if arterial stiffness can be attenuated even if the aerobic exercise duration is less than 30 min.

Arterial stiffness is one of many factors than can lead to cardiovascular disease. Research has shown that HI-RT can affect arterial elasticity in a negative manner (Cortez-Cooper et al. 2005; Miyachi et al. 2003). For this reason, this study sought to determine which training protocol is the best to conserve arterial elasticity while enhancing muscle strength and hypertrophy.

Problem Statement

In the long run, arterial stiffness becomes a problem for individuals who train with high intensities when resistance training. This increased stiffness in the arteries can lead to arteriosclerosis, which increases the risk of hypertension and other cardiovascular diseases. Therefore this study was beneficial to see the best training method to attenuate decreases in arterial elasticity while increasing muscle strength and size. To do so, we recruited sedentary or active males, and asked them to complete 8 weeks of resistance training with and without BFR.

Statement of Purpose

This study was conducted to compare the effects of various resistance training protocols [1) low-load weight training with BFR in combination with low-intensity aerobic training. 2) Traditional high intensity weight training. 3) Traditional high intensity weight training in combination with moderate-intensity aerobic training] on adaptations in body composition, muscular strength, arterial stiffness, and hemodynamics in young males.

Significance of Study

This research study would impact the risks resistance exercise training has on musculoskeletal injury and arterial stiffness. There is a need to find alternative training methods that are effective to improve muscular hypertrophy and strength while reducing negative health outcomes such as decreased arterial elasticity. If we can conclude that low-intensity BFR training can elicit the same muscular adaptations as HI-RT, it would be very beneficial for all populations due to the lower risk of a musculoskeletal injury. In addition, this study could lead to a more efficient approach to reducing the negative effects of HI-RT on arterial elasticity. Other studies found that 30 min of moderate-intensity aerobic training could attenuate the effects of HI-RT on arterial elasticity, but this study will focus on how the arteries respond to only 15 min. If arterial stiffness can be prevented with only a 15-min walk/jog, people that have time constraints would benefit by exercising less time while conserving arterial function.

Assumptions

The following assumptions were made:

1. Participants would give their full effort in all tests to the best of their respective abilities.
2. Participants would answer the pretest questionnaires honestly and to the best of their understanding.
3. Participants would be hydrated and fasted for all of their testing sessions.
4. All equipment used was reliable and accurate results were provided.
5. Participants would not participate in any physical activity apart from the study.

Limitations

1. The study might not be representative to the population due to the participants being volunteers, not randomly sampled.

2. The study was limited to only male volunteers from the Rio Grande Valley area.

3. All medical information and health history was self-reported by the participant.

4. Physical activity and nutrition outside the laboratory could not be monitored.

Delimitations

The study was delimited as follows:

1. Subjects had to be between the ages of 18-40.

2. Participants had to be sedentary or physically active (physically active but not participating in regular structured exercise training) and healthy (not known to have any diseases).

3. Subjects were excluded if they were diagnosed with diseases (e.g. Diabetes, heart disease, etc.), had other musculoskeletal injury impairing physical performance, history of blood clots, varicose veins, deep vein thrombosis (DVT), or other conditions that would impede venous return.

4. Participants with signs or symptoms of cardiovascular disease were not allowed to participate in the study.

Research Questions

To accomplish the purpose of this study, the following research questions were addressed:

1. Did the HI+AE and BFR groups result in significant differences in arterial elasticity and hemodynamics compared to HI?
2. Did BFR result in similar muscular and strength adaptations as both high-intensity groups?
3. Did the HI+AE and BFR groups result in significantly greater VO2peak compared to HI?
4. Did the HI+AE and BFR groups result in similar increases in lean mass with further decreases in fat mass compared to HI?

Hypotheses

The study was designed to address the following hypothesis:

1. HI+AE and BFR groups will result in significant improvements in arterial elasticity and hemodynamic responses than HI.

2. BFR will result in similar muscular and strength adaptations compared to both high-intensity groups.

3. HI+AE and BFR will result in significant increases in VO2peak when compared to HI.

4. HI+AE and BFR will result in similar increases in lean mass as HI with further decreases in fat mass.

Operational Definitions

To aid the reader, the following terms are defined as used in the present study:

iDXA: Measures body composition as the subject lays down, and it is the gold standard when it comes to body composition measurements.

Blood Flow Restriction (BFR): A training method partially restricting arterial inflow and fully restricting venous outflow in working musculature during exercise.

Biodex: A computer assisted machine that is used to assess muscle strength, power, etc.

Hypertrophy: Refers to an increase in muscular size achieved through exercise.

Arterial compliance: The measurement of the elastic properties of the arteries, which has an inverse relationship with arterial stiffness.

Hemodynamics: Analysis of physical aspects of blood circulation and blood flow.

Hydration: Hydration status was considered adequate when urine specific gravity measured lower than 1.010, as determined by a clinical urine refractometer.

PAR-Q: PAR-Q (Physical activity readiness questionnaire) is a screening tool that is designed to determine whether a subject may perform the exercise in a safe and risk free manner.

Pulse Wave Velocity: Noninvasive assessment of arterial compliance in which velocity of blood pressure wave forms traveling between three different sites are measured.

Summary

Arterial elasticity has become one of the most important factors influencing the onset of cardiovascular disease (Riley et al., 1986; Cecelja et al., 2012). It is widely known in the exercise science field that resistance training can lead to significant decreases in arterial elasticity (Heffernan, 2007). Low-intensity BFR training has been known to attenuate arterial stiffness while enhancing muscle hypertrophy and strength (Spranger, 2015). A training modality that is known to increase arterial elasticity is aerobic training (Jablonski., 2015). This mode of training attenuates arterial stiffness even if HI-RT is performed simultaneously (Kawano, 2006). The minimum length that the aerobic session should be performed is not yet clarified, therefore this study will provide evidence to know if arterial stiffness can be attenuated even with less than 30 min of aerobic training per session. In addition, this study will provide evidence to know which protocol is best for the enhancement of muscle hypertrophy and strength.

Chapter 2 contains a review of selected literature related to arterial elasticity, BFR training, hemodynamics, and the effects different protocols have on variables. Chapter 3 contains a discussion of the methodology used in this study. Chapter 4 displays the results of this study. Chapter 5 contains a discussion of the results, a summary of the study, conclusions that were made, and recommendations for future research.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to know how body composition, muscular strength, arterial stiffness, and hemodynamics respond to different training protocols in young, healthy males. One of the most common problems in the fitness industry can be the decrease in arterial elasticity following HI-RT. Since this type of training causes stiffness, BFR training protocols have been developed in order to attenuate arterial stiffness while still obtaining similar musculoskeletal benefits that resistance training offers. Different protocols have been developed, but these protocols have not been efficient at replicating the effects of HI-RT on muscular hypertrophy and strength. The following literature review will explain the methods used in each study and their results. (1) Blood flow restriction, (2) Arterial Elasticity, (3) Hemodynamics, and the (4) Different Protocols will be explained in the review.

Blood Flow Restriction Training

HI-RT can cause many serious injuries if not performed correctly. According to Suga et al. (2012), "Resistance training with high-intensity mechanical load can achieve muscle hypertrophy and strength increase; however, it generates intensive stress in musculoskeletal and cardiovascular systems." This was one of the main reasons for the implementation of BFR training. With a lighter load, BFR training can actually elicit similar results as HI-RT when it comes to muscular hypertrophy (Yasuda et al., 2011; Vechin et al., 2018). The following studies will discuss the use of BFR to enhance muscular strength and hypertrophy while minimizing the risk of injury.

Hypertrophy and Strength

A study conducted by Curty et al. (2018) evaluated the effects of HI-RT with BFR on muscle damage markers and perceptual and cardiovascular responses. Only healthy men ages 25-27 participated in this study, therefore the age population for this study was very narrow. The results showed a post-exercise decrease in range of motion (ROM) for both groups, the HI-RT and HI-RT + BFR. This decrease in range of motion signifies that the damage to the working muscle was high. Although the damage was high for both groups, the HI-RT + BFR group returned to normal ROM ranges faster than the HI-RT group. This study found no significant difference in arm circumference from pre to post exercise for the HI-RT + BFR group while the HI-RT only group did show a significant increase. The findings of this study show that HI-RT + BFR may increase the rate of recovery after high muscle damage. In addition, the BFR group had no significant increase in arm circumference post exercise.

Yasuda et al. (2011) investigated how combining low-intensity BFR with traditional HI-RT would affect muscle adaptations. Forty young men ages 22-32 years were recruited to participate in this study. All of them were recreationally active, but none of the subjects participated in strength training at least 6 months before the start of the study. There were 4 groups in this study design: HI-RT, low-intensity resistance training + BFR, a combined high and low-intensity group, and a control group. Each of the groups was composed of ten subjects. Subjects completed bench press exercises 3 times per week for a total of 6 weeks. The results for this study showed a significant increase in muscle strength for both the HI-RT group and the combination group. Low-intensity BFR training did not show similar strength increases as the other two training groups. When it comes to muscle hypertrophy, the three training groups significantly increased the muscle cross sectional area. The authors speculated that the small increase in strength for the low-intensity resistance training group was due to muscle hypertrophy alone, not neural adaptations. This study showed that low-intensity BFR training can elicit similar hypertrophic results when compared to HI-RT.

One study performed on the elderly population, investigated the effects of low-intensity resistance training with BFR compared to traditional HI-RT on the quadriceps muscle (Vechin et al, 2018). The strength and muscle mass of each participant was measured pre to post training to see which type of training elicited better results. There were three groups in this study: HI-RT, low-intensity training + BFR, and a control group. The training groups completed 12 weeks of training in the leg press. The findings were similar to the study discussed previously. Both groups had similar muscle cross sectional area increases, but the HI-RT group significantly increased their strength while the low-intensity BFR group did not. The difference in strength was quite large, with the low-intensity group increasing 17% while the HI-RT group increased 54%. This study also suggests that low-intensity BFR training can elicit the same hypertrophic response as HI-RT, but strength increases could be higher with HI-RT.

One other study that compared the effects of BFR training to traditional HI-RT was developed by Neto et al. (2014). This study focused on investigating the acute effects of high-intensity squats on muscular fatigue. 12 athletes were split into two groups, one with BFR and the other with no BFR. Muscle strength and muscular fatigue were assessed during the study. Both groups performed a series of squats with an 80% 1RM on the eighth day of the study. The results showed that there was a significant reduction in muscle strength in both groups, but the

BFR group had further decreases. This reduction in strength could mean HI-RT with BFR can lead a greater amount of muscular fatigue than traditional HI-RT.

Metabolic Stress

Suga et al. (2009), took a different approach to investigating the effects of BFR. This study focused more investigating the intramuscular metabolism during low-intensity resistance training with BFR. 26 healthy subjects with an average age of 22 years participated in this study. 3 groups were developed for this study: a low-intensity resistance training (20% 1 RM), a low-intensity resistance training with BFR (20% 1RM), and a HI-RT (65% 1 RM). Subjects performed 30 repetitions per min doing unilateral plantar flexion. The researchers used P-magnetic resonance spectroscopy to measure intramuscular metabolites, pH, and muscle fiber recruitment during the exercise. The authors concluded that metabolic stress in the muscle was increased by applying BFR when performing low-intensity exercise. Although there was an increase in metabolic stress following BFR, HI-RT still had significantly more metabolic stress than low-intensity BFR. This study suggests that metabolic stress could be greater in HI-RT than with low-intensity training with BFR.

Arterial Elasticity

Arterial stiffness has become a problem in the fitness industry when it comes to resistance training. Studies have reported an association between arterial function indices and cardiovascular risk factors, as well as the risk of incident cardiovascular events, including coronary heart disease and stroke (Zoungas, 2007). Evidence suggests that individuals who performed HI-RT on a regular basis demonstrated lower levels of carotid arterial compliance than their sedentary peers in young and middle-aged populations (Cortez- Cooper et al. 2005; Miyachi et al. 2003). A decrease in arterial elasticity is associated with mortality caused by cardiovascular disease. According to Laurent et al. (2007), "Arterial stiffness and wave reflections are now well accepted as the most important determinants of increasing systolic and pulse pressure in our aging community." For this reason, finding ways to decrease arterial stiffness is imperative to prevent future cardiovascular complications. BFR training and aerobic training are two ways to maintain or even improve arterial elasticity.

One study involving 23 young women with an average age of 29 years, investigated the effects that Hi-RT on arterial stiffness (Cortez-Cooper, 2005). The participants performed several upper and lower body exercises during the training program. Some of the exercises being performed were: bench press, overhead press, squat, and dumbbell curl. The subjects trained 4 days per week for 11 weeks as part of the study. Before and after those 11 weeks, arterial compliance and wave reflection were measured. Results showed that both arterial stiffness and wave reflection increased significantly compared to the start of the training program. These results support the evidence that HI-RT increases arterial stiffness.

Ozaki et al. (2013) investigated the effects of HI-RT and low-intensity BFR on arterial compliance. 19 young men ages 22-32 years were split into two groups: HI-RT and low-intensity BFR. The variables being tested were the subjects' arterial compliance, strength, and muscle cross-sectional area. The HI-RT group performed bench press 3 days per week for 6 weeks at an intensity of 75% 1 RM. The low-intensity BFR group performed the same protocol, but at an intensity of 30% 1RM. Both groups increased their strength and muscle cross-sectional area significantly, but there was one major difference in the third variable. Arterial compliance significantly decreased in the HI-RT group while the low-intensity BFR group did not change. The authors suggested that the change in arterial compliance was due to the fact that blood pressure increased greatly during HI-RT.

Another study conducted by Kawano et al. (2006) investigated how a combination of HI-RT followed by moderate-intensity endurance training would affect arterial compliance. 39 normotensive, healthy men participated in this study, in which maximum strength and carotid arterial compliance were measured. The subjects were divided into three groups: a moderate-intensity resistance training only, HI-RT in combination with moderate-intensity aerobic training, and a control group. All participants performed 3 sessions per week for 4 months. Subjects in the combination group performed 3 sets of 8-12 exercises at 80% 1RM. This was followed by a 30 min cycle exercise at 60% of maximum HR. The moderate-intensity group completed 3 sets of 14-16 exercises at 50% 1RM. The results for this study showed that the moderate-intensity resistance training group significantly decreased arterial compliance. The combination group saw no significant change in arterial compliance when compared to the control group. This evidence suggests that arterial stiffness can be attenuated by incorporating at least 90 min of moderate-intensity endurance training per week to an exercise plan.

Tagawa et al. (2018) investigated the effects of resistance training on arterial compliance and plasma endothelin-1 levels in healthy men. Since endothelin-1 is considered a vasoconstrictor, the goal of this study was to know if the decrease in arterial compliance is due to plasma endothelin levels. A total of 14 young healthy men participated in this study, where hemodynamics, muscle strength, arterial compliance, and plasma vasoconstrictor levels were measured pre and post training. The training group performed bicep curls at 10 repetitions per set, 5 sets per session, 3 sessions per week, for 4 weeks at 75% 1RM. The control group did not train, only the pre and post training measures were evaluated in that group. The present study showed that a 4-week resistance training program can significantly decrease arterial compliance in young males. This decrease in arterial compliance can be attributed to the increase in plasma endothelin-1 because it is a potent vasoconstrictor. The decrease in the artery's diameter increased blood pressure, causing arterial stiffness.

A study conducted by Kosaki et al. (2019) investigated the effects of combining resistance training with endurance training or arterial stiffness in older adults. 56 subjects ages 65-79 participated in this study, in which their pulse wave velocity (PWV) was measured after exercise. There were two groups in the study, a resistance training only and a resistance training plus aerobic training group. The subjects performed the training program twice a week for 12 weeks. The results showed that the resistance training group increased aortic arterial stiffness post-training. Although the aortic artery's stiffness increased, leg arterial stiffness did not decrease following the training period. The combination group did not increase arterial stiffness at all. A 20 to 25 min bout of light aerobic exercise before resistance training positively changed the results of the combination group.

Hemodynamics

Hemodynamics refers to the physical study of flowing blood and of all the solid structures through with it flows (McDonald, 1974). One of the aims of the present study is to compare how each protocol affects hemodynamic variables and the extent to which they are affected. This section will focus on highlighting the findings in previous research performing HI-RT and BFR on hemodynamic variables.

High-Intensity Resistance Training

A previous study performed on older adults investigated the effects of a 24-week training regimen on hemodynamic responses (Vincent et al., 2003). Subjects were divided into 3 groups: low-intensity (LI) (50% of 1RM), high-intensity (HI) (80% of 1RM), and a control group. Both training groups resistance trained three times per week. Hemodynamic variables such as systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), and resting heart rate (HR) were measured at baseline and after 24 weeks of training. It was found that SBP significantly decreased in the HI group compared to the LI group. In addition, MAP significantly decreased from pre- to post-training in the HI group while no significant change in DBP or HR were seen. The results for this study suggest that HI-RT can induce some positive effects on hemodynamics in older adults. The present study will seek to find how these variables are affected in untrained young males.

Kawano et al. (2006) measured several hemodynamic variables before and after training three times per week for four months. Subjects were separated into three groups: a moderate-intensity resistance training only, a combined resistance training plus aerobic exercise group, and a control group. Results showed that carotid SBP and DBP, brachial SBP and DBP, and brachial pulse pressure (PP). In addition, there were no significant differences in stroke volume index (SVI) and HR following any protocol. These results show that moderate-intensity resistance training does not elicit substantial changes in hemodynamics, even when aerobic exercise is performed after training.

Blood Flow Restriction Training

A previously mentioned study by Ozaki et al. (2013) investigated how BFR training affects several hemodynamic variables after six weeks of resistance training in young males. Subjects were separated into two groups, a HI-RT and low-intensity BFR. Both groups performed the bench press exercise three days per week for six weeks. It was found that carotid SBP and DBP, brachial SBP and DBP, and brachial PP had no significant changes in the BFR group following the six weeks of training. This study concluded that BFR training had no significant negative or positive effects on the measured hemodynamic variables after six weeks.

Renzi et al. (2010) investigated how walking with BFR would acutely affect hemodynamic responses in young adults. Subjects walked with and without BFR on two different days and hemodynamics were measured during the tests. It was found that the exercise-induced blood pressure response was significantly higher in the BFR protocol when compared to the control. Authors suggested that these increases were due to elevations in total peripheral resistance. As expected, stroke volume had less increase and higher HR response in the BFR protocol, which is due to the decrease in venous return with BFR. Because of this, double product was significantly higher in the BFR groups when compared to control. These results suggest that BFR places a greater demand on the cardiovascular system, therefore the present study will seek to investigate how these variables adapt to 8 weeks of BFR training.

Different Protocols

Changing the training principles or parameters of the training protocol of a study can change the whole result of the overall study. "Blood flow restriction training technique can be affected by several factors resulting in changes in responses to training (Karabulut, 2011)." Even changing a small part of a protocol can have significant effect in how the results are expressed. In the case of these studies, occlusion pressure, exercise intensity, or length of exercise were investigated to see the effects these variables had on the results.

Occlusion Pressure

A study conducted by Dankel et al. (2016), investigated the acute muscular response to two different BFR protocols. 15 participants with an average age of 25 years participated in this study. The participants were requested to perform 4 sets of elbow flexions with each arm. Each arm had different occlusion pressure and different types of bands. One of the arms had a threecentimeter elastic cuff inflated to 160 mmHg while the other arm used a five-centimeter nylon cuff. This cuff was inflated to 40% of subject's occlusion pressure. EMG amplitude, acute muscle thickness, and post-exercise maximal voluntary contraction were measured during the study, but no difference was seen between protocols. This study provides some insight when it comes to having a set pressure for all individuals. Relative pressures have to be used because every individual is different, therefore the occlusion pressure should not be set the same for everyone.

Exercise Length

Another study conducted by Karabulut et al. (2020), investigated the effects of an aerobic training session length on arterial elasticity. The researchers measured several hemodynamic variables and arterial elasticity at baseline in order to compare the results with the post-training results. Participants performed aerobic exercise on a treadmill on three different days. The intensity for all three days stayed the same at 65% VO2max, but the length of the sessions varied per day. Subjects ran for 30, 45, or 60 min and post-exercise measurements were measured 3 times after the session culminated. The findings for this study indicate that there is a dose-response relationship of moderate-intensity aerobic exercise on arterial elasticity. This finding can be very interesting to compare with the arterial elasticity results for this future study.

Exercise Intensity

Lixandrao et al. (2015) developed a study which sought to investigate the effects that the intensity of an exercise and the occlusion pressure have when training with BFR. 26 young subjects with an average age of 27 years, participated in this procedure. There were a total of five groups, each of them with different exercise intensities and occlusion pressures. Each subject's dynamic strength and cross-sectional area of the quadriceps were measured before and after the training plan. Each protocol seemed to have different effects on muscle cross-sectional area and strength. When it comes to hypertrophy, the BFR protocols with higher intensities had similar results as the HI-RT group. Strength wise, neither occlusion or exercise intensity affected muscle strength when comparing all the BFR protocols. The HI-RT had significantly better results for both muscle strength and hypertrophy.

The last study presented tested arterial elasticity response to an 8-week resistance training protocol with BFR (Karabulut et al., 2020). 15 male subjects participated in this study where hemodynamics and arterial elasticity were measured pre and post training. The protocol was structured so that the subjects trained 3 times per week for a total of 8 weeks. Subjects performed 4 sets of 20 repetitions at 20-30% of their 1 RM. It was concluded that this protocol showed better results than previous protocols when it comes to attenuating arterial stiffness.

Conclusion

This review gives an insight to how every aspect of the research is connected. BFR protocols have been implemented partly to help attenuate arterial stiffness. Not only BFR training has helped reduce arterial stiffness, but aerobic exercise has also been proven to help reduce arterial stiffness in many studies that were mentioned before. Even if HI-RT was performed simultaneously, endurance training helped attenuate the stiffness. In addition, the studies that were mentioned in this review found no negative effects on hemodynamics with HI-RT and BFR training. This study will seek to determine if an addition of 15 min of aerobic exercise can positively affect hemodynamics. It was seen that different protocols caused different results in many studies. The variables that changed in some studies were: occlusion pressure, exercise intensity, and exercise length. Those three variables can change the whole outcome of the study, therefore every protocol should take them into account. Another factor that was seen in these results was that BFR training did not elicit the same strength adaptations as HI-RT. Even though strength was not increased as much with BFR, hypertrophy seemed to be similar to the effects seen in HI-RT. This study may provide an insight to determine which protocol can be the best to enhance muscle hypertrophy, strength, and arterial elasticity.

Chapter 3 delivers the methodology used for this study, Chapter 4 presents the results, Chapter 5 presents the discussion and contains a summary of the whole study, conclusions, and future recommendations.

CHAPTER III

METHODOLOGY

The purpose of this study was to know how arterial stiffness, body composition, arterial stiffness, and hemodynamics respond to different training protocols in young males. In this chapter, the methods and procedures used in the course of this study are presented and discussed. Included in this chapter are the following topics:

Participants

A total of 32 sedentary or recreationally active males participated in this study. Prior to participating, the participants were taken through the study design. The University of Texas Rio Grande Valley Institutional Review Board approved the study procedure for human subjects. All participants were required to sign an informed consent document, health status questionnaire, PAR-Q, and a questionnaire to identify individuals with diseases affecting venous return. All of these forms had to be completed and signed before starting any procedure. Participants were recruited from the University of Texas Rio Grande Valley area via email, flyer, and by word of mouth. Inclusion and exclusion criteria were taken into account before the participants were included in the study.

Inclusion Criteria

1. Participants were between the ages of 18-40
2. Participants were sedentary or physically active (physically active but not participating in regular structured exercise training) and healthy (not known to have any diseases).

Exclusion Criteria

1. Individuals diagnosed with diseases (e.g. Diabetes, heart disease, etc.),
2. Individuals who have other musculoskeletal injury impairing physical performance, have history of blood clots, varicose veins, deep vein thrombosis (DVT), or other conditions that would impede venous return.
3. Participants who were outside the 18–40-year age range.
4. Participants taking medication that may interfere with vascular function.

Research Design

This between-subjects randomized study design compared the effects of three different resistance training protocols on muscular strength, arterial elasticity, hemodynamics, and body composition. A total of 21 visits were required in this study.

Questionnaires

The following questionnaires were completed by the participants to determine exclusion/inclusion criteria while collecting information to reduce the potential influence of physical activity and diet.

1. Health Status Questionnaire – used to determine if participants met study inclusion criteria and if they had any preexisting conditions that warrant exclusion. Also used to record medications taken by the participants
2. Physical Activity Readiness Questionnaire (PAR-Q) - a common method of uncovering health and lifestyle issues prior starting an exercise program.
3. Questionnaire to Identify Individuals with Diseases Affecting Venous Return – used to identify if any participant suffered from a disease affecting venous return.

Experimental Protocol

Every procedure in this study was conducted in the Neuromuscular Performance Laboratory (BVOTS building, Room 216 and Wellness Room (Cortez Hall, Room 220). Scheduling was agreed on by each subject and researcher at a time that was available for both. Subjects had to be fasted for at least eight hours and hydrated prior to the testing sessions. Each subject's hydration level was measured with a digital clinical urine refractometer. Any value at or below 1.010 was considered passing for hydration. The study consisted of a total of 10 weeks, with weeks 1 and 10 used for pre- and post-testing while weeks 2-9 consisted of the training protocols.

On the first session, participants were asked to complete several questionnaires and were given a brief introduction to the study procedures. Each participant answered the PAR-Q questionnaire, and any "Yes" as an answer resulted in exclusion from the study. In addition, after the PAR-Q was completed, a health status questionnaire and a questionnaire to identify individuals with diseases affecting venous return were answered. Once the subject qualified for the study, an informed consent had to be signed in order to start any testing procedures. The completion of these forms concluded the first session.

The second session consisted of collecting measurements using the Lunar intelligent DXA (iDXA), Biodex, and a One-Repetition Maximum test (1RM). Session two would last approximately 100 min. Before starting, height and weight were measured using a wall stadiometer and bioelectrical impedance analysis, respectively. Participants were then instructed to lie down for an iDXA scan, which measured their body composition. The Biodex machine was then used to measure the quadriceps isometric and isokinetic strength and fiber type percentage. Lastly, a 1RM test was administered to get the exact amount of weight that each participant could move for only one repetition. With the 1RM values, the exact weight with which each participant would train was calculated.

The third session consisted of using Hypertension Diagnostic Instrument (HDI), Sphygmocor, and a treadmill to measure VO2peak. Session three would last approximately 90 min. When measurements involving the HDI and Sphygmocor were performed, participants were instructed to lie down for 10 min prior to any measurement. Baseline arterial elasticity and hemodynamics were measured using HDI (noninvasive equipment that measures arterial elasticity by placing a sensor over the radial artery in the right wrist and a cuff in the left arm to measure blood pressure). Pulse wave analysis was measured using Sphygmocor by placing a specialized cuff on the right arm, one inch above the antecubital fossa. PWV was also measured using SphygmoCor, which was conducted noninvasively using a pencil-type sensor which was placed over the carotid artery.

After completion of the pre-testing sessions, participants were randomly assigned to one of the three groups performing one of the designed resistance training for a total of 8 weeks, 2 times a week with at least 48 hours between sessions. Total volume of workload for each exercise was calculated using the following equation: Volume = set *x* total number of repetitions for each set *x* load. Volume for the BFR group was ~80% of the volume for each high-intensity group. Every session was performed under the supervision of the investigators. The following procedures were used for the training sessions.

Traditional High-Intensity Group

The traditional High-Intensity Group (HI) included the weight training sessions in which participants attended the training room and performed the specified routine. The high-intensity weight training began with the participant warming up by completing a 5-min walk at 3.5 mph. Subjects then performed the training routine which consisted of 6 exercises (leg press, leg curl, leg extension, incline bench press, lat pulldown, and shoulder press) at an intensity of 70-80% of their 1RM. Participants performed 3 sets consisting of 8 - 11 repetitions, and rested 2 min between each set and 2 min between each exercise. The traditional high intensity sessions took approximately 60 min to complete.

Low-Intensity BFR Group

The low-intensity BFR Group (BFR) included the weight training sessions with BFR in which the participant attended the training room and performed the specified routine. BFR resistance training began with the participant warming up by completing a 5-min walk at 3.5 mph. BFR cuffs were applied to their arms and legs and were raised to the calculated pressure following established protocol. Final pressure was set at 160 mmHg for the legs (120 mmHg for arms) in the 1^{st} training session. Initial pressure was set at 35-45 mmHg for the legs and 20 to 30 mmHg for the arms. Once the initial pressure was set, the cuffs were inflated to 120 mmHg for legs (80 mmHg for arms) and additional pressure increments of 20 mmHg were applied until capillary refill time (CRT) was at 2 seconds. CRT is a measure of the time (in seconds) that takes for the capillary bed to regain its color after pressure has been applied. The CRT was determined by pressing the thumb into the quadriceps muscle immediately above the knee and releasing to check how quickly (in seconds) the blanched (white) area returns to normal color (Amano et al., 2016). This procedure has been used to determine the right amount of pressure that the circulation in the limbs is restricted but not completely blocked. Once the final pressure was set, subjects then performed the training routine which consisted of 6 exercises (leg press, leg curl, leg extension, incline bench press, lat pulldown, and shoulder press) in which they performed 4 sets for 20 reps, each set all at an intensity of 20-40% of their 1RM. Participants rested 30-60 seconds between each set and 2 min between each exercise. Following the resistance training session, subjects performed a 15-min walk at 40% of their peak oxygen uptake (VO2peak). The following formula was used to calculate each participant's treadmill speed in the BFR group: (((VO2peak*0.4)-3.5)/0.19)/26.8)). Low-intensity BFR sessions took approximately 90 min to complete.

Traditional High-Intensity + Aerobic Group

The traditional high-intensity + aerobic group (HI+AE) included the resistance training sessions in which the participants attended the training room and performed the specified routine. The traditional high-intensity weight training in combination with aerobic exercise began with the participant warming up by completing a 5-min walk at 3.5 mph. Subjects then performed the training routine which consisted of 6 exercises (leg press, leg curl, leg extension, incline bench press, lat pulldown, and shoulder press) at an intensity of 80% of their 1RM. Subjects performed 3 sets consisting of 8-11 repetitions and rested 2 min between each set and 2 min between each exercise. Following the resistance training session, the participant performed 15-min walk/jog at 60% of their peak oxygen uptake (VO2peak). The following formula was used to calculate each participant's treadmill speed in the BFR group: (((VO2peak*0.6)-3.5)/0.19)/26.8)). The traditional high intensity + aerobic sessions took approximately 75 min to complete.

Instruments

Wall Stadiometer and Bioelectrical Impedance Analysis

Height was measured to the nearest 0.5 cm using a wall stadiometer. Weight was measured to the nearest 0.1 kg using a digital electronic scale (DC-430U Dual Frequency Total Body Composition Analyzer, Tanita, Tokyo, Japan).

Clinical Urine Refractometer

Participants were required to provide a urine sample at the beginning of each testing session. Hydration was measured by using 3-4 drops of the urine sample on to the lens of the urine refractometer (PAL-10S Urine Specific Gravity Refractometer, Atago, Tokyo, Japan). The digital device measured hydration and gave a value after approximately 3 seconds. Any value on or below 1.010 was considered as hydrated. The device was then cleaned, and the rest of the urine was discarded into the biohazard waste.

Dual Energy X-ray Absorptiometry (iDXA)

Body composition was measured using iDXA (GE Lunar Prodigy, enCORE software version 6.70.021; GE Healthcare, Madison WI) and was performed before (session 2) and after the training program (session 20).

Biodex

The Biodex Multi-Joint System – Pro is a computer assisted machine that is used to assess muscle strength, power, etc. One isometric test was performed to measure maximal strength. This test was conducted at least twice. If the difference in the values was more than 10%, the test would be repeated to ensure data consistency. This procedure was used to measure quadriceps isometric and isokinetic strength using a variety of tests. Two isokinetic tests were administered (60°/s and 180°/s) to know how muscle force would respond to the training protocols. Lastly, the Thorstensson Fatigue Test was performed to measure muscle fiber type changes from pre- to post-training. Data was recorded before (session 2) and after the training program (session 20).

One-Repetition Maximum Testing (1RM)

Leg press, leg extension, leg curl, incline bench press, lat pulldown, and shoulder press machines were used for this study. Trained personnel were present to instruct participants on the appropriate lifting technique. The 1RM protocol for each piece of equipment was: (1) proper positioning based on manufacturer recommendations; (2) complete a warmup set of 5-10 repetitions at ~50% of estimated maximal strength; (3) after 1 min rest, another set of 3-5 repetitions at ~75% of estimated maximal strength; (4) After 2 min rest, the load was increased for one repetition, with this step repeating, until a maximum was achieved. The goal was to achieve a maximum strength value within five 1-RM attempts. Data was recorded before (session 2) and after the training program (session 20).

HDI/PulseWave CR-2000TM Research Cardiovascular Profiling System

Measurements related to the heart and blood vessels were recorded by using HDI, which uses noninvasive equipment that measures arterial elasticity by placing a sensor over the radial artery in the right wrist and a cuff in the left arm to measure blood pressure. Before any measurement was taken, each subject was instructed to lie supine for 10 min. An appropriate-sized blood pressure cuff was placed on the left-upper arm one inch above the antecubital space. As the subject laid supine, the radial artery was palpated to find their pulse. Once the strongest pulse of the radial pulsation was found, the participant's right wrist was secured with a wrist immobilizer. A piezoelectric-based sensor was placed over the right radial artery and adjusted to a signal strength between 18% and 24%. The data was recorded before training (session 3) and after weight training ended (session 21). Large artery elasticity (LAE), small artery elasticity (SAE), SBP, DBP, HR, PP, cardiac ejection time (CET), cardiac output (CO), stroke volume (SV), systemic vascular resistance (SVR), and total vascular impedance (TVI) were measured using this device. Data was recorded before (session 3) and after the training program (session 21).

Pulse Wave Analysis/Velocity

Pulse Wave Analysis was measured using SphygmoCor® Pulse Wave Analyzer (AtCor Medical Pty. Ltd., Sydney Australia) by placing a specialized cuff on the participant's right arm, one inch above the antecubital fossa. Measurements were taken twice to ensure consistency in the results. PWV measurements were also conducted non-invasively using SphygmoCor, considered as the gold standard for analyzing PWV. The pressure waveforms and amplitudes were obtained from the carotid artery with a pencil-type probe incorporating a high-fidelity strain gauge-transducer. Data was recorded before (session 3) and after the training program (session 21).

VO2 Peak

In order to obtain each participant's peak oxygen uptake (VO2peak), a standard treadmill protocol was used. The Bruce Protocol, which consists of incremental stages, was performed until volitional fatigue. The treadmill speed and incline increased every three min, until the participant could no longer keep running. Maximal HR and total time to exhaustion were measured for each participant. VO2peak was calculated using the following formula: 14.76-(1.38*Time)+(0.451*Time*Time)-(0.012*Time*Time*Time). Data was recorded before (session 3) and after the training program (session 21).

Data Analysis

One-way analysis of variance (ANOVA) was used to test baseline differences between groups and percent (%) changes from pre- to post-training. Percent changes were calculated using the following formula: (post – pre)/pre x 100. When there were no significant differences between groups at baseline, changes between groups comparing pre- and post-training were assessed by a two-way analysis ANOVA with repeated measures (group (HI vs. HI+AE vs. BFR) x time (pre vs. post)). When ANOVA with repeated measures detected a significant difference, LSD comparison test was performed for a post hoc analysis. A separate one-way ANOVA was performed for each group as a follow up test when there was a significant time main effect to determine which group experienced significant changes from baseline. When homogeneity assumption was violated, Kruskal-Wallis, a non-parametric test, was used to analyze differences from pre-to post-training between groups. Analysis of covariance (ANCOVA) was used when there were significant differences between groups at baseline. ANCOVA results were reported for trunk to total fat mass ratio, legs to total fat mass ratio, and arms to total fat mass ratio. All data were expressed as means ± SE in the text, figures, and tables. An alpha of 0.05 was used to determine statistical significance and data were analyzed using SPSS for Windows (IBM Corporation, New York, USA).

CHAPTER IV

RESULTS

This study was conducted to compare the effects of various resistance training protocols [1) low-load weight training with BFR in combination with low-intensity aerobic training. 2) Traditional high intensity weight training. 3) Traditional high intensity weight training in combination with moderate-intensity aerobic training on adaptations in body composition, muscular strength, arterial stiffness, and hemodynamics in young males.

Subject Characteristics

A total of 34 male participants were recruited to participate in the study. 32 of these participants were able to complete all 21 sessions. These participants were recruited from the community and through recruitment at The University of Texas Rio Grande Valley in Brownsville, TX.

Table 1. Participant Characteristics (Mean ± SE)

Variable	**HI (n = 10)**	**HI + AE (n = 11)**	**BFR (n = 11)**
Age (yrs)	20.5 ± 0.89	21.09 ± 1.04	21.18 ± 0.58
Height (cm)	173.8 ± 2.59	173.97 ± 1.54	171.58 ± 1.97
Weight (kg)	76.39 ± 4.96	77.60 ± 4.29	74.86 ± 3.40
BMI	25.25 ± 1.45	24.84 ± 1.34	25.39 ± 0.97
VO2peak (ml/kg/min)	35.01 ± 2.04	37.47 ± 2.26	38.57 ± 2.37

Body Composition

Table 2 shows the effects on body composition from pre- to post-training. One-way ANOVA found no significant baselines differences between groups for all variables except: Trunk Fat Mass Ratio, Legs Fat Mass Ratio, and Arms Fat Mass Ratio. ANCOVA detected no significant differences between groups. Two-way ANOVA with repeated measures found no significance for all condition and time main effects or condition*time interactions.

Table 2. Body Composition Results (Values reported as Mean ±SE.)

	HI (n = 10)		HI + AE (n = 11)		BFR (n = 11)	
Variable	**PRE**	**POST**	**PRE**	**POST**	**PRE**	**POST**
Total Mass (kg)	76.5 ± 4.9	77.69 ± 5.4	78.1 ± 4.3	78.2 ± 4.3	75.4 ± 3.4	75.9 ± 3.2
Lean Mass (kg)	49.5 ± 2.8	50.7 ± 2.9	52.8 ± 1.8	53.4 ± 1.8	51.4 ± 2.4	51.7 ± 2.3
Fat Mass (kg)	24.2 ± 2.5	24.2 ± 2.9	22.5 ± 3.0	22.0 ± 2.9	21.3 ± 1.5	21.4 ± 1.5
Tissue Fat (%)	32.4 ± 1.7	31.60 ± 1.9	28.9 ± 2.3	28.2 ± 2.2	29.1 ± 1.4	29.1 ± 1.4
Android Fat (kg)	2.2 ± .27	2.18 ± .32	1.8. ± .36	1.8 ± .35	1.9 ± .22	1.9 ± .22
Android Lean (kg)	3.51 ± .20	3.50 ± .20	3.5 ± .13	3.5 ± .14	3.5 ± .13	3.5 ± .14
Gynoid Fat (kg)	4.07 ± .45	3.97 ± .48	3.6 ± .45	3.5 ± .43	3.3 ± .21	3.2 ± .21
Gynoid Lean (kg)	8.2 ± .54	8.49 ± .57	8.4 ± .30	8.6 ± .30	8.2 ± .35	8.4 ± .35

Figure 1a shows the change in bodyweight from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect ($p=0.04$) with no significant condition main effect or condition*time interactions. The follow up test showed that no significant differences from baseline were detected in any condition. Figure 1b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 1.2 %, 0.29 %, and 1.32 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 1a. Bodyweight

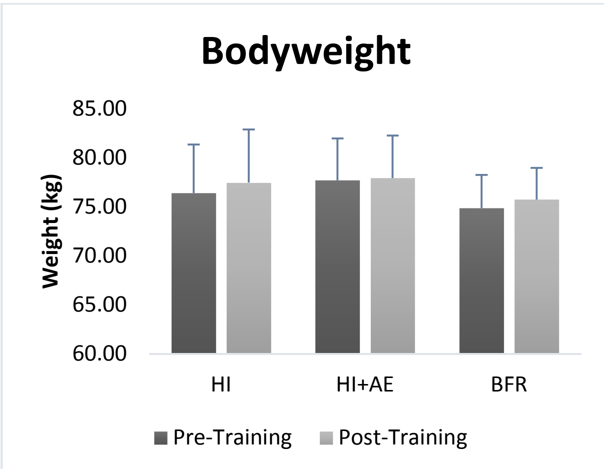


Figure 1b. Change in Bodyweight (%)

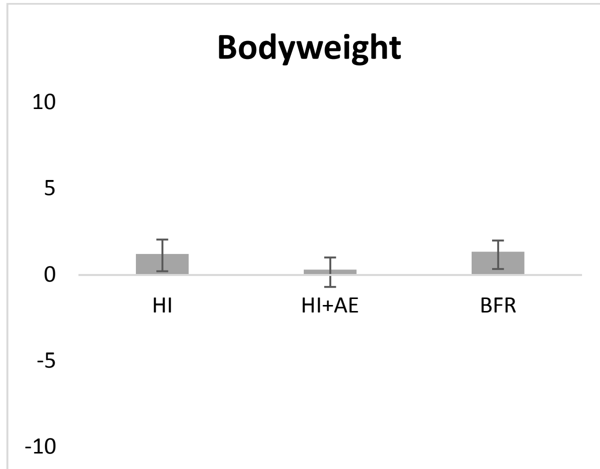


Figure 2 shows the change in total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effects or condition*time interactions.

Figure 2. Total Mass

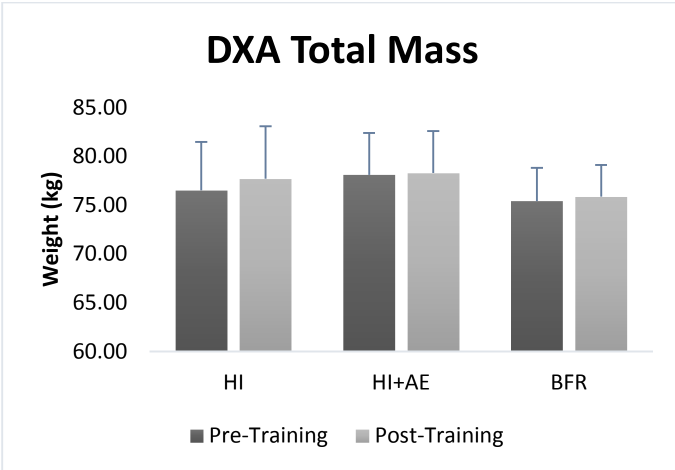
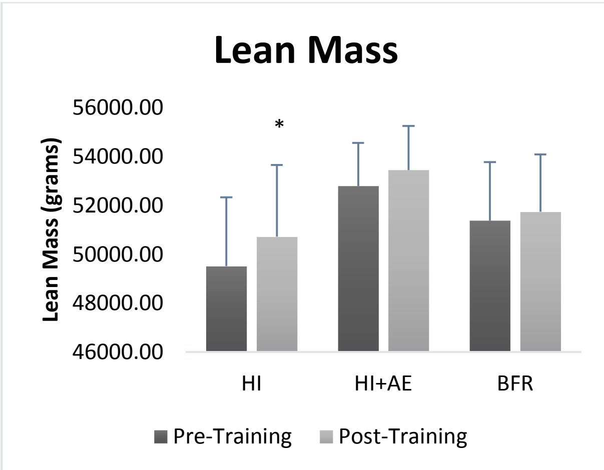


Figure 3 shows the change in lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect ($p=0.001$), with no significant condition main effect or condition*time interactions. The follow up test showed that HI significantly increased from baseline ($p = 0.020$). Figure 3b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 2.45 %, 1.26 %, and 0.75 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 3a. Lean Mass



*Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 3b. Change in Lean Mass (%)

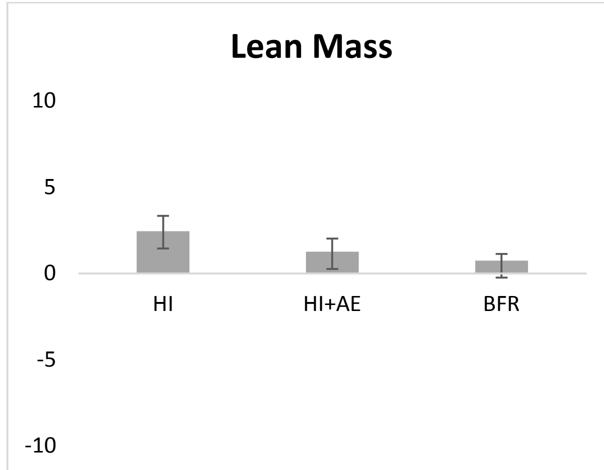


Figure 4 shows the change in fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effects or condition*time interactions.

Figure 4. Change in Fat Mass

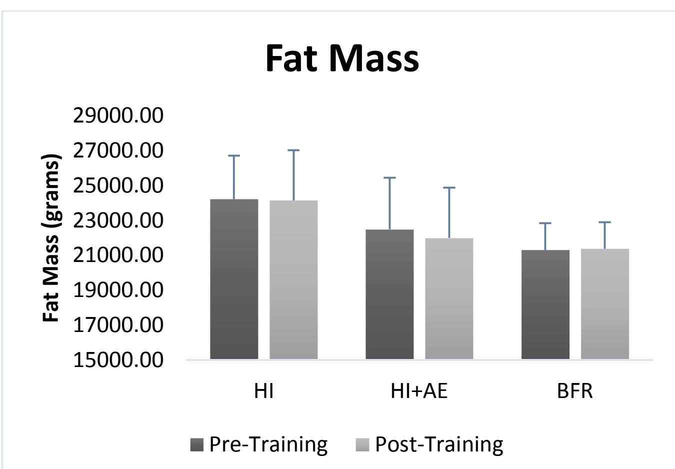


Figure 5a shows the change in arms region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.013), with no significant condition main effect or condition*time interactions. The follow up test showed that a trend was detected in HI (p=0.064) and HI+AE (p=0.054) conditions from baseline. Figure 5b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -6.98 %, -3.75 %, and 0.34 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 5a. Arms Region % Fat

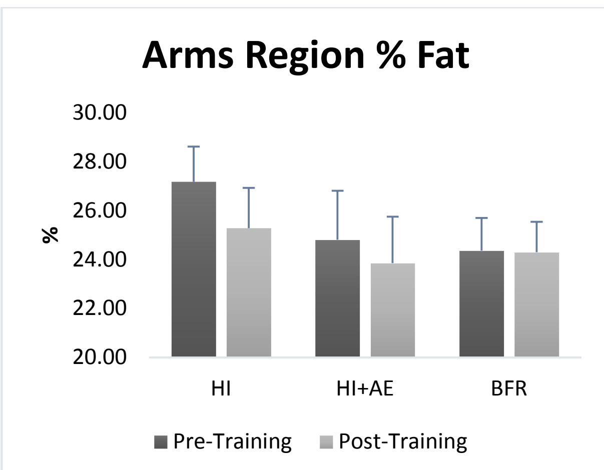
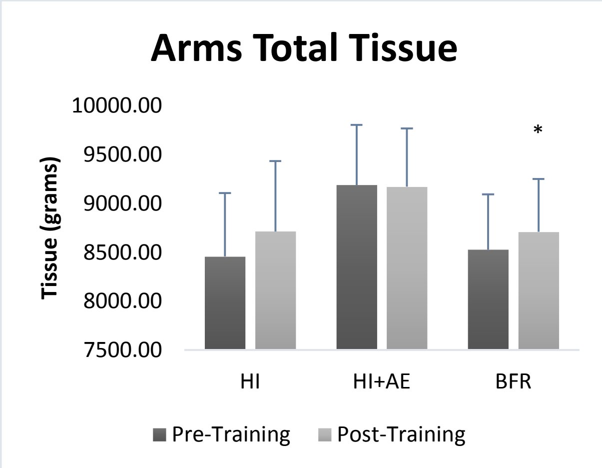
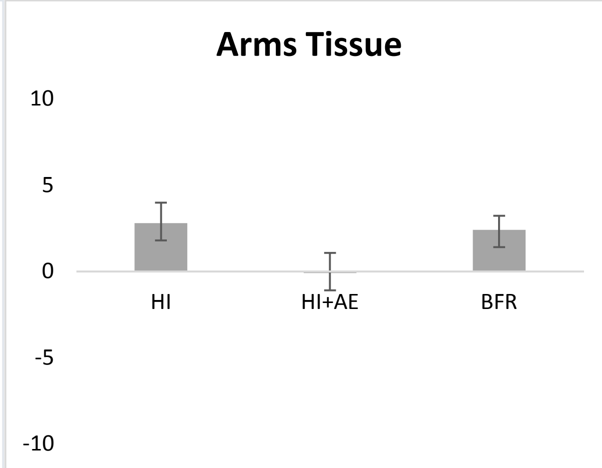


Figure 5b. Change in Arms Region % Fat (%)

Figure 6a shows the change in arms tissue from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.014), with no significant condition main effect or condition*time interactions. The follow up test showed that BFR significantly increased from baseline (p=0.020) and a trend was found in HI (p=0.051). Figure 6b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 2.79 %, -0.09 %, and 2.41 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 6a. Arms Tissue **Figure 6b.** Change in Arms Tissue (%)





* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 7 shows the change in arms fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effects or condition*time interactions.

Figure 7. Arms Fat Mass

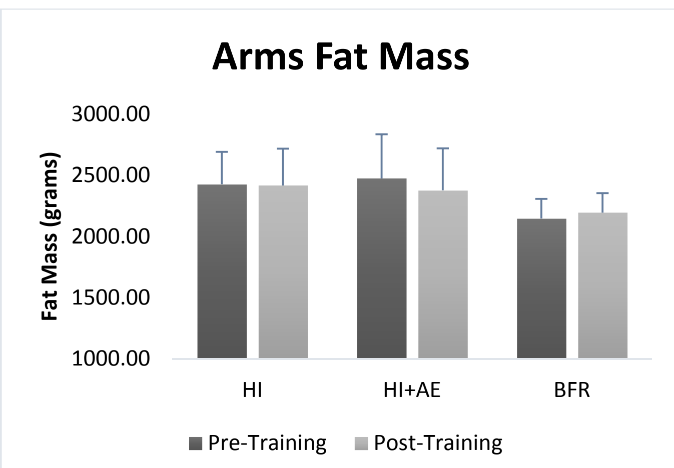


Figure 8a shows the change in arms lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI significantly increased from baseline (p=0.020) and a trend was found for the BFR condition (p=0.067). Figure 8b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 4.47 %, 1.30 %, and 2.58 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 8a. Arms Lean Mass

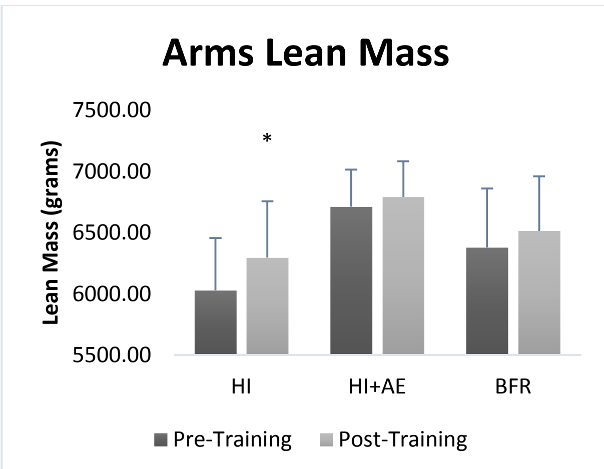
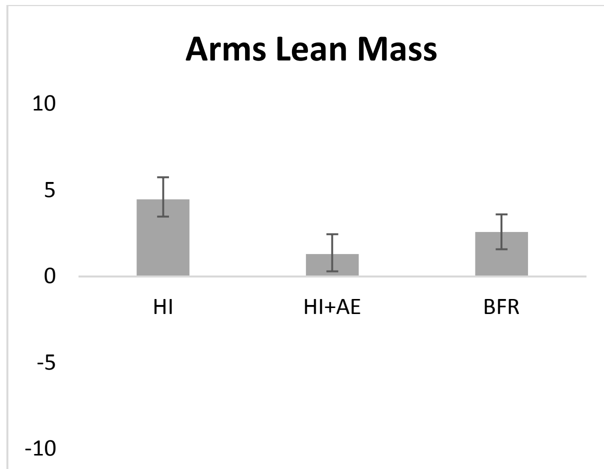


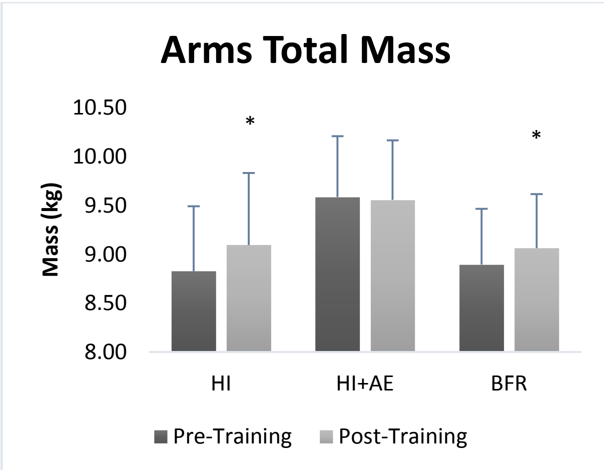
Figure 8b. Change in Arms Lean Mass (%)

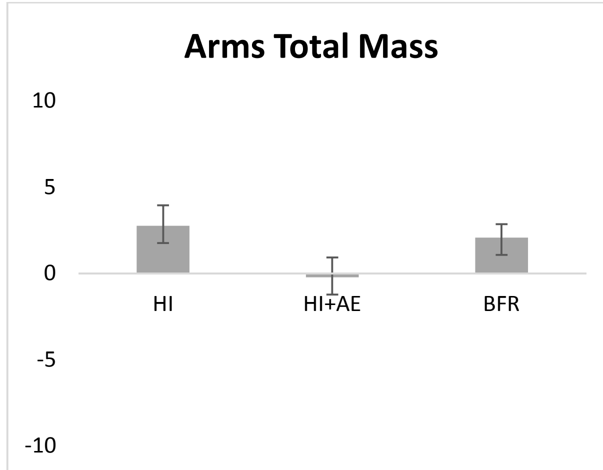


* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 9a shows the change in arms total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.019), with no significant condition main effect or condition*time interactions. The follow up test showed that significant increases were seen from baseline for the HI (p=0.049) and BFR conditions (p=0.036). Figure 9b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 2.77 %, -0.22 %, and 2.08 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 9a. Arms Total Mass **Figure 9b.** Change in Arms Total Mass (%)

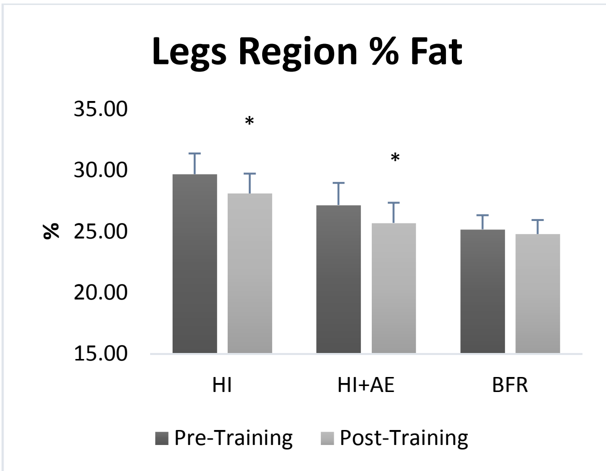




* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 10a shows the change in legs region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that significant decreases from baseline were seen in the HI (p=0.014) and HI+AE conditions (p=0.008). Figure 10b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -5.27 %, -5.07 %, and 1.42 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 10a. Legs Region % Fat



* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 10b. Change in Legs Region % Fat (%)

Figure 11a shows the change in legs tissue from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.030), with no significant condition main effect or condition*time interactions. The follow up test showed that a trend was found for the HI condition (p=0.062) compared to baseline. Figure 11b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 2.05 %, -0.02 %, and 1.35 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 11a. Legs Tissue

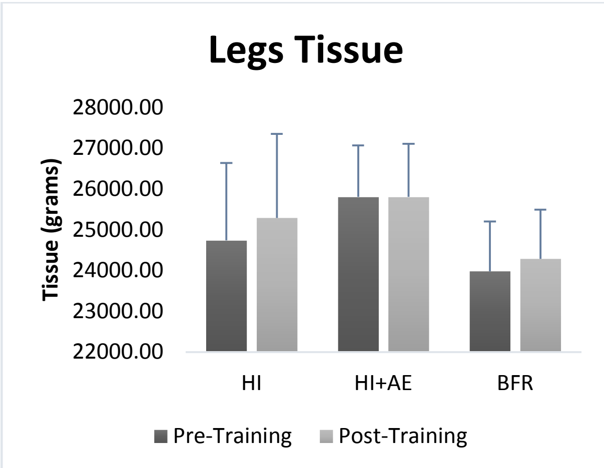


Figure 11b. Change in Legs Tissue (%)

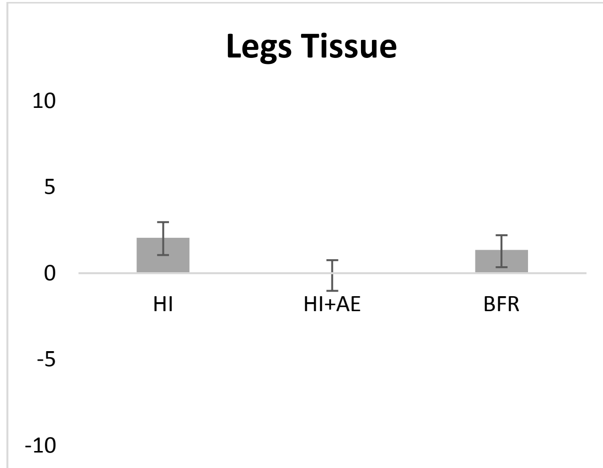


Figure 12a shows the change in legs fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.005) with no significant condition main effect. There was a trend for a condition*time interaction (p=0.077). . The follow up test showed that HI+AE significantly decreased from baseline (p=0.018). Figure 12b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -3.54 %, -5.10 %, and -0.07 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 12a. Legs Fat Mass

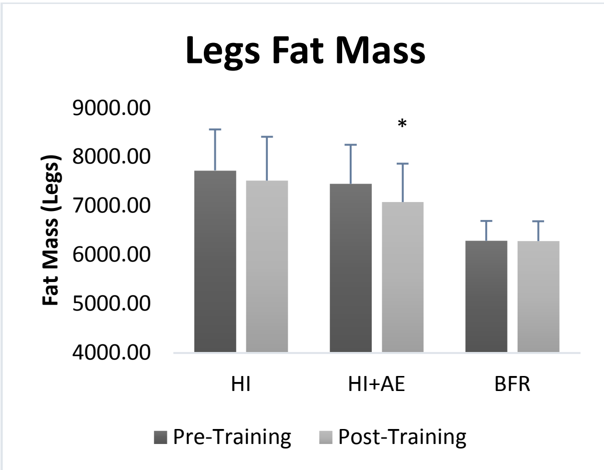
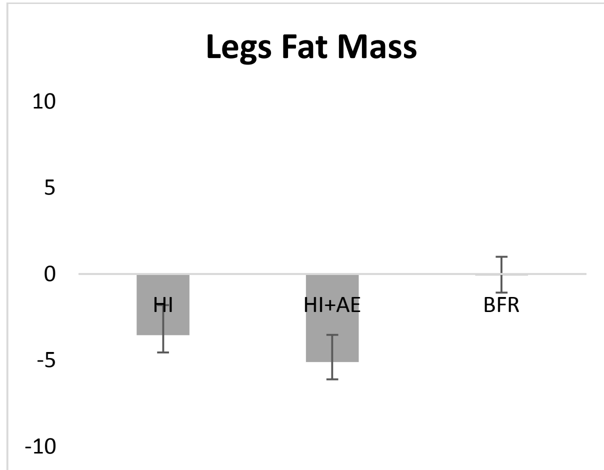


Figure 12b. Change in Legs Fat Mass (%)



* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 13a shows the change in legs lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that a trend was found for the HI (p=0.051) and BFR conditions (p=0.078) from baseline. Figure 14b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 4.50 %, 2.20 %, and 1.89 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 13a. Legs Lean Mass

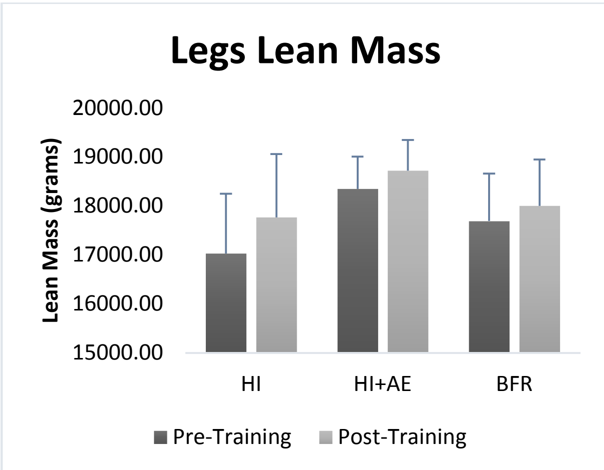


Figure 13b. Change in Legs Lean Mass (%)

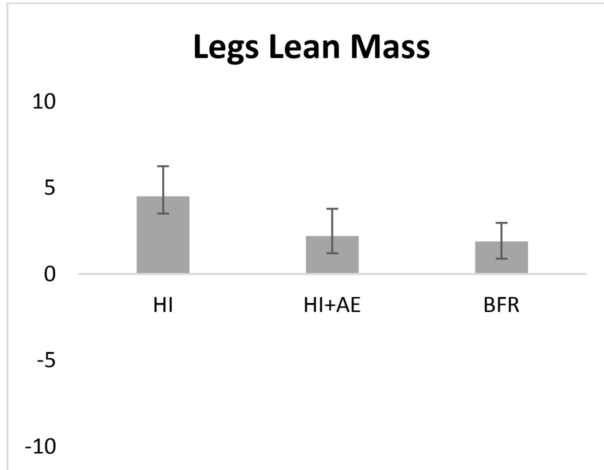


Figure 14a shows the change in legs total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.029), with no significant condition main effect or condition*time interactions. The follow up test showed that a trend was found for the HI condition (p=0.056) from baseline. Figure 14b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 1.91 %, -0.05 %, and 1.29 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 14a. Legs Total Mass

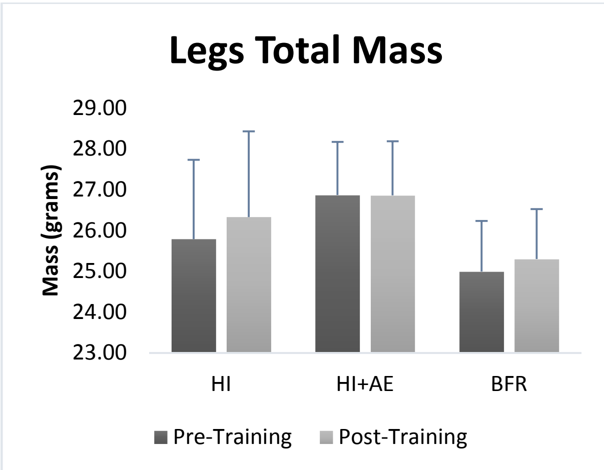


Figure 14b. Change in Legs Total Mass (%)

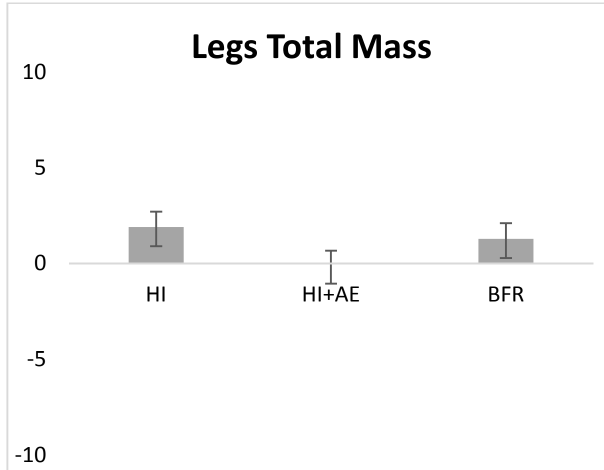


Figure 15 shows the change in trunk region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 15. Trunk Region % Fat

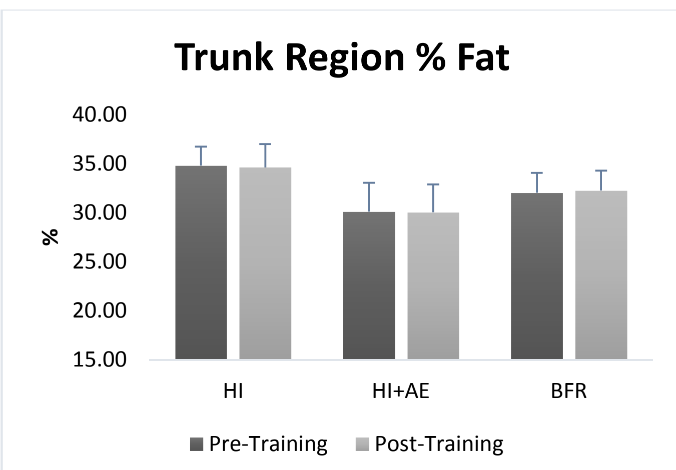


Figure 16 shows the change in trunk tissue from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed

by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 16. Trunk Tissue

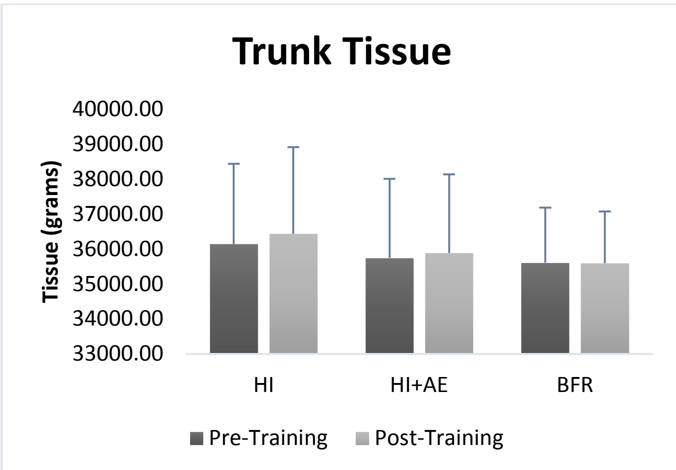


Figure 17 shows the change in trunk fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 17. Trunk Fat Mass

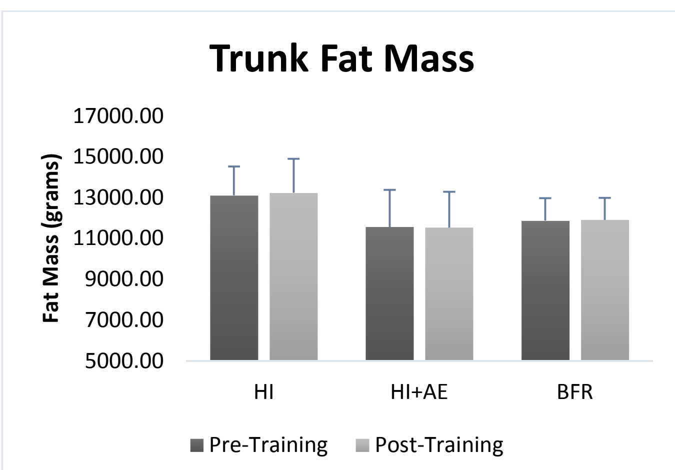


Figure 18 shows the change in trunk lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed

by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 18. Trunk Lean Mass

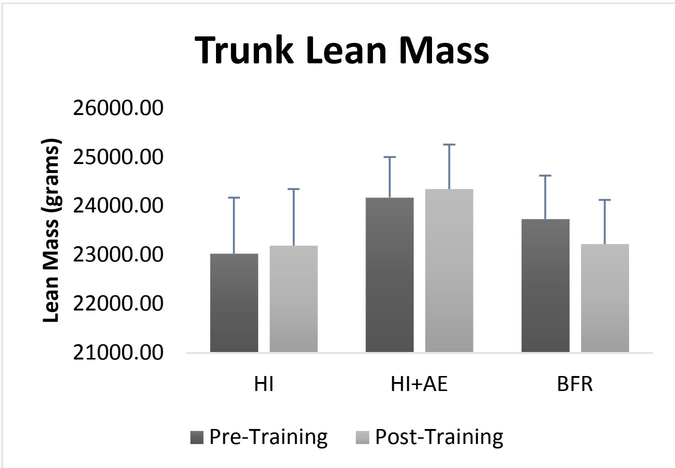


Figure 19 shows the change in trunk total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 19. Trunk Total Mass

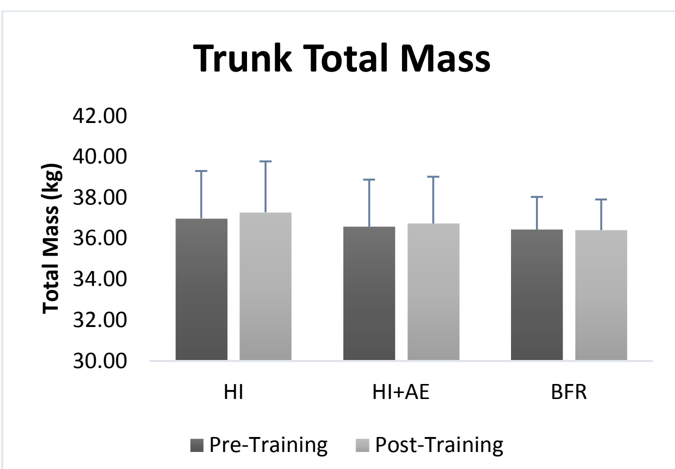


Figure 20 shows the change in android tissue percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 20. Android Tissue % Fat

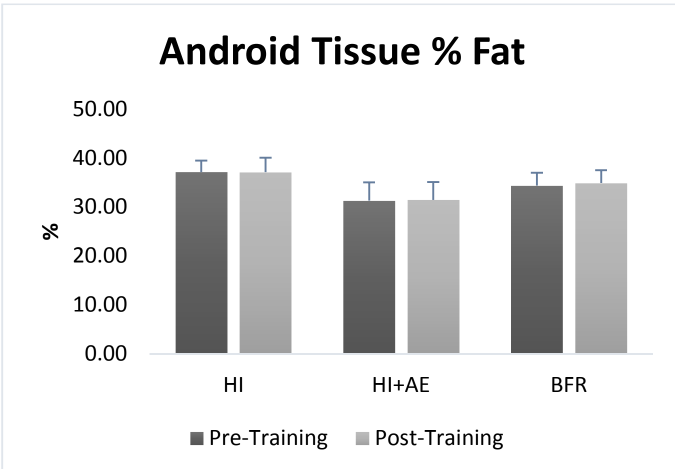


Figure 21 shows the change in android tissue from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 21. Android Tissue

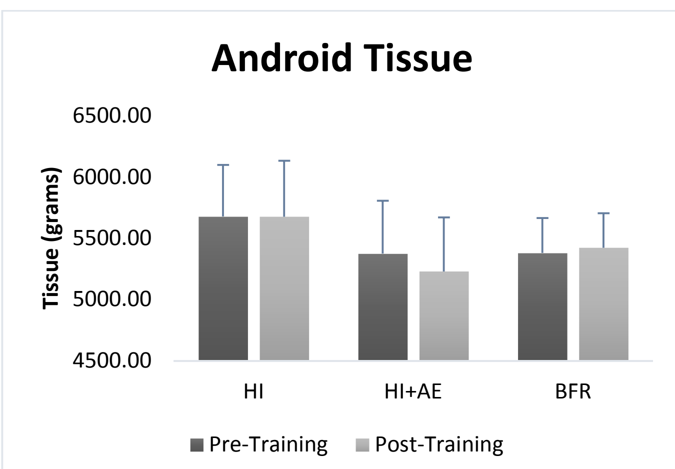


Figure 22 shows the change in android fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed

by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 22. Android Fat Mass

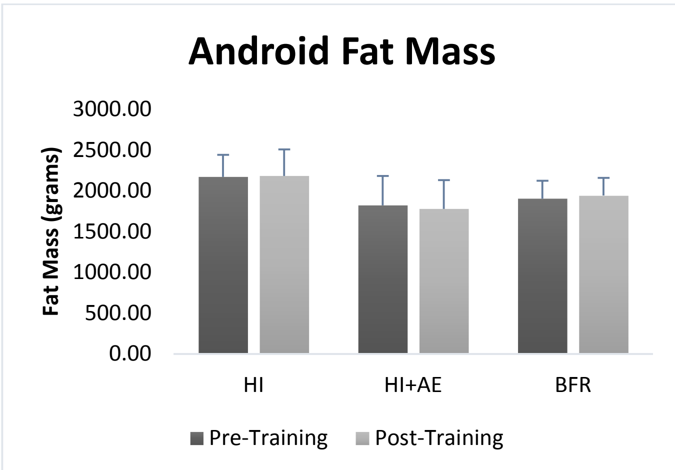


Figure 23 shows the change in android lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 23. Android Lean Mass

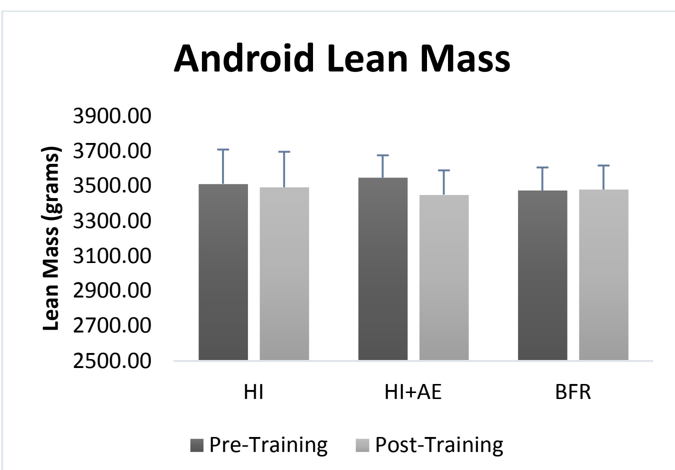


Figure 24 shows the change in android total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed

by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 24. Android Total Mass

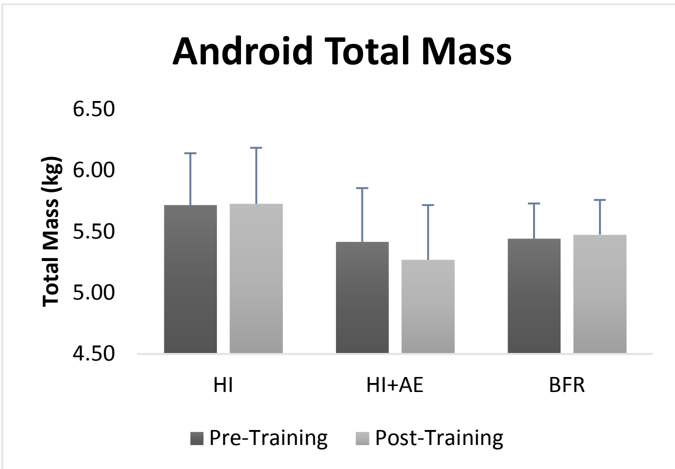
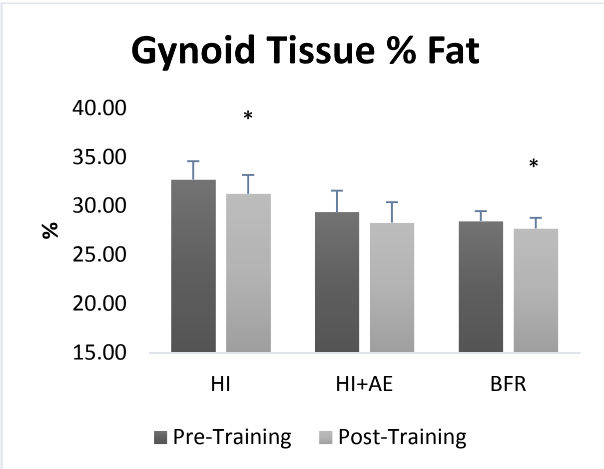
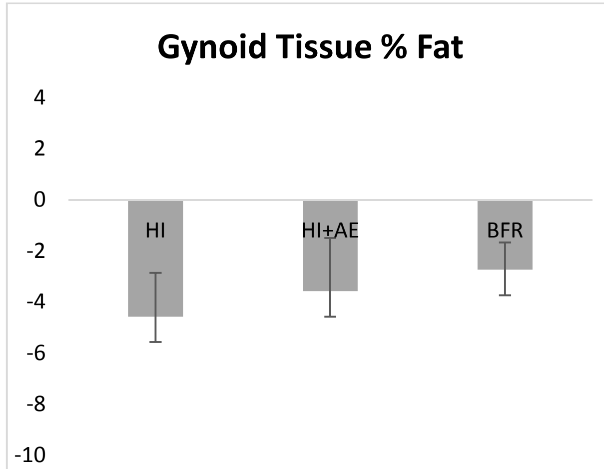


Figure 25a shows the change in gynoid tissue percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.027) and BFR (p=0.031) significantly decreased from baseline. Figure 25b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -4.57 %, -3.57 %, and -2.74 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 25a. Gynoid Tissue % Fat **Figure 25b.** Change in Gynoid Tissue % Fat (%)





* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 26 shows the change in gynoid tissue from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 26. Gynoid Tissue

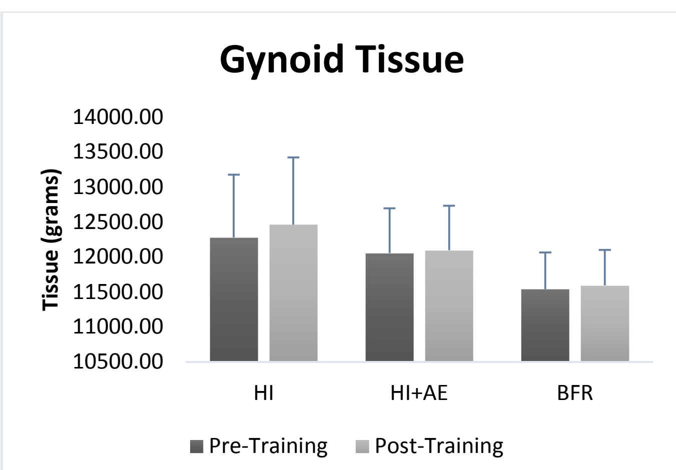


Figure 27a shows the change in gynoid fat mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.026), with no significant condition main effect or condition*time interactions. The follow up test showed that no significant difference from baseline were found in any condition. Figure 27b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -3.25 %, -3.0 %, and -2.09 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 27a. Gynoid Fat Mass

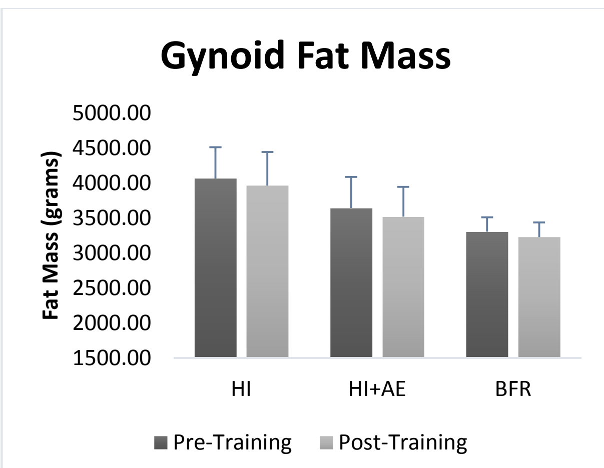


Figure 27b. Change in Gynoid Fat (%)

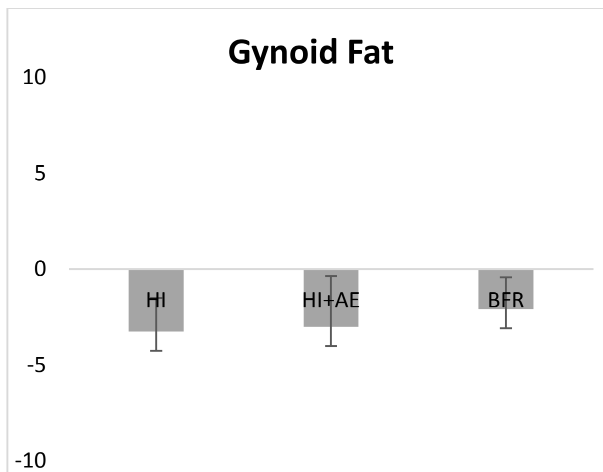
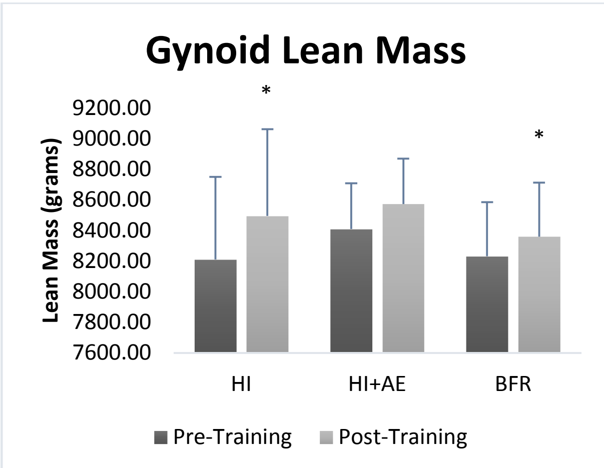


Figure 28a shows the change in gynoid lean mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.043) and BFR (p=0.002) significantly increased from baseline and a trend was seen in HI+AE (p=0.061). Figure 28b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -3.25 %, -3.0 %, and -2.09 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 28a. Gynoid Lean Mass



* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 28b. Change in Gynoid Lean Mass (%)

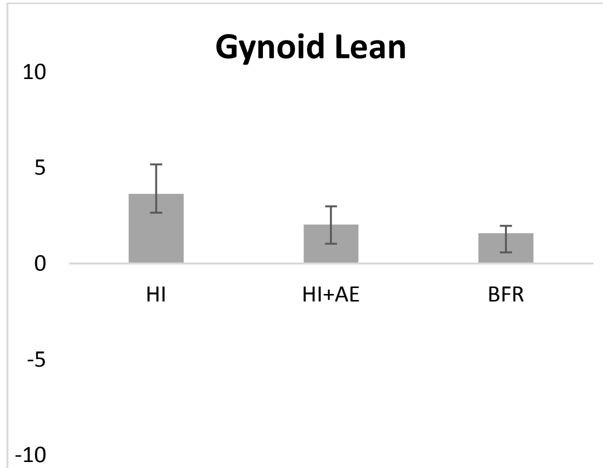


Figure 29 shows the change in gynoid total mass from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 29. Gynoid Total Mass

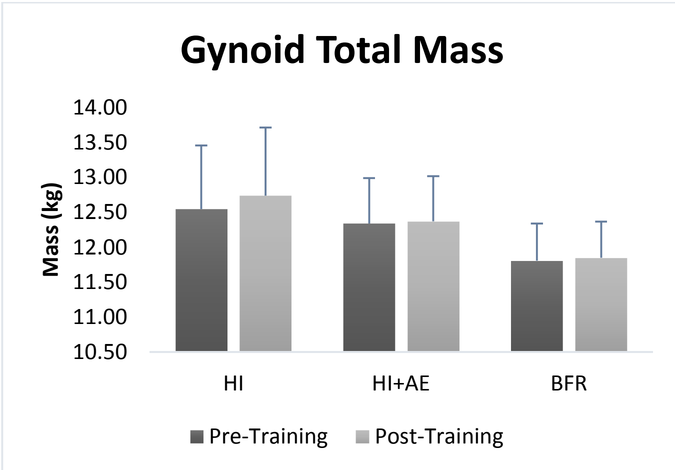


Figure 30a shows the change in total tissue percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.014), with no significant condition main effect or condition*time interactions. The follow up test showed that a trend was found in the HI+AE condition (p=0.059) from baseline. Figure 30b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -3.0 %, -2.16 %, and -0.10 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 30a. Total Tissue % Fat

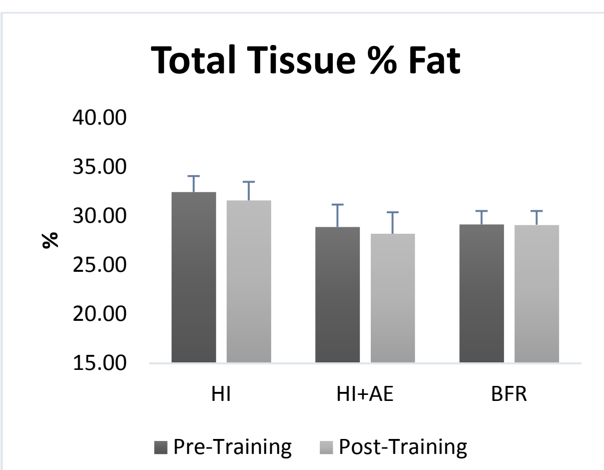


Figure 30b. Change in Total Tissue % Fat (%)

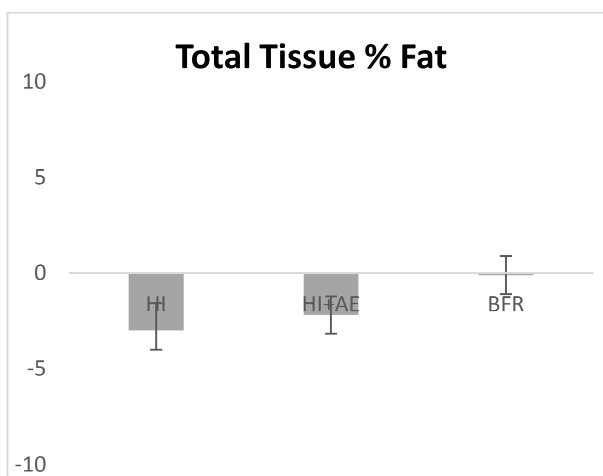


Figure 31a shows the change in total region percent fat from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.016), with no significant condition main effect or condition*time interactions. The follow up test showed that a trend was found in the HI+AE condition (p=0.062) from baseline. Figure 31b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -2.88 %, -2.15 %, and -0.09 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 31a. Total Region % Fat

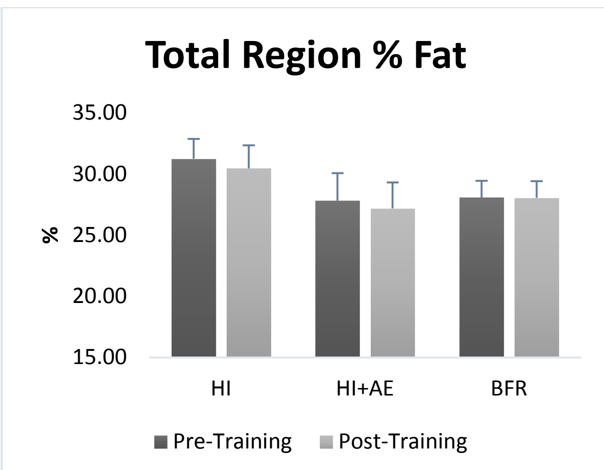


Figure 31b. Change in Total Region % Fat (%)

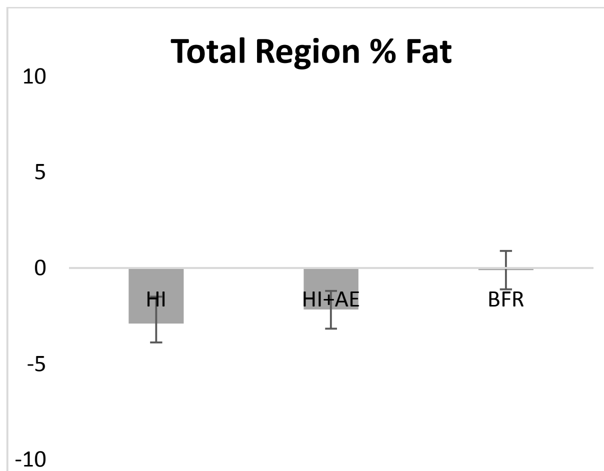


Figure 32 shows the change in total tissue from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 32. Total Tissue

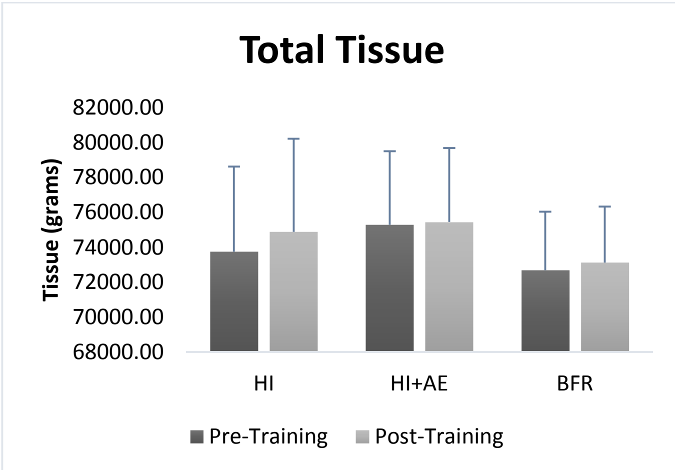


Figure 33 shows the change in trunk to total fat mass ratio from pre- to post-training. A one-way analysis of covariance (ANCOVA) was run to examine whether post values differed between conditions while controlling for baseline values. Preliminary checks were completed to assess the assumptions of normality, linearity, homogeneity of regression slopes, and homogeneity of variance. A Shapiro-Wilk test indicated that results were normally distributed in the HI, HI+AE, and BFR groups (p=0.473, p=0.192, p=0.653, respectively).

A scatterplot indicated that the relationship between dependent variable and the covariate was linear in all three conditions. Additionally, the scatterplot suggested that the regression slopes were similar and an F test indicated that there was not an interaction between dependent variable and covariate, $F(2, 26) = 0.97$, p = .391. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(2, 29) = 1.27$, p=0.296. After controlling for pre values, there was not a significant effect of condition on Trunk Fat Mass Ratio, $F(2, 28) = 0.29$, p=0.748, $\eta_p^2 < .02$. Estimated marginal means were similar in the HI (*M* = .535, *SE* = .004), HI+AE (*M* = .537, *SE* = .004), and BFR (*M* = .533, *SE* = .004) conditions.

Figure 33. Trunk to Total Fat Mass Ratio

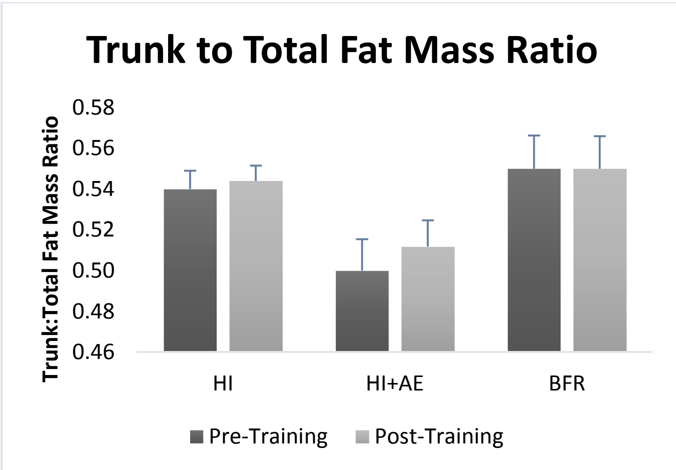


Figure 34 shows the change in legs to total fat mass ratio from pre- to post-training. A one-way analysis of covariance (ANCOVA) was run to examine whether post values differed between conditions while controlling for baseline values. Preliminary checks were completed to assess the assumptions of normality, linearity, homogeneity of regression slopes, and homogeneity of variance. A Shapiro-Wilk test indicated that results were normally distributed in the HI, HI+AE, and BFR groups (p=0.245, p=0.613, p=0.474, respectively).

A scatterplot indicated that the relationship between dependent variable and the covariate was linear in all three conditions. Additionally, the scatterplot suggested that the regression slopes were similar and an F test indicated that there was not an interaction between dependent variable and covariate, $F(2, 26) = 1.384$, p=0.269. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(2, 29) = .13$, p=0.876. After controlling for pre values, there was not a significant effect of condition on Legs Fat Mass Ratio, $F(2, 28) = 0.55$, p=0.581, $\eta_p^2 < .04$. Estimated marginal means were similar in the HI ($M = .314$, $SE = .004$), HI+AE ($M = .311$, $SE = .004$), and BFR ($M = .317$, $SE = .004$) conditions.

Figure 34. Legs to Total Fat Mass Ratio

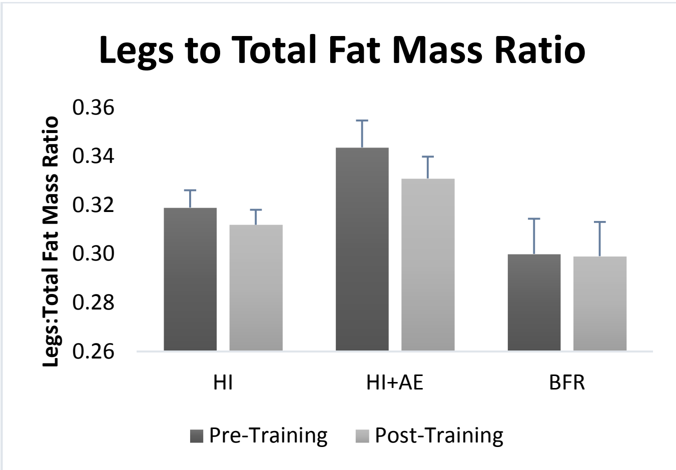


Figure 35 shows the change in arms to fat mass ratio from pre- to post-training. A one-way analysis of covariance (ANCOVA) was run to examine whether post values differed between conditions while controlling for baseline values. Preliminary checks were completed to assess the assumptions of normality, linearity, homogeneity of regression slopes, and homogeneity of variance. A Shapiro-Wilk test indicated that results were normally distributed in the HI, HI+AE, and BFR groups (p=0.300, p=0.348, p=0.240, respectively).

A scatterplot indicated that the relationship between dependent variable and the covariate was linear in all three conditions. Additionally, the scatterplot suggested that the regression slopes were similar and an F test indicated that there was not an interaction between dependent variable and covariate, $F(2, 26) = 2.741$, p=0.083. Levene's test indicated that the assumption of homogeneity of variance was not violated, $F(2, 29) = 2.13$, p=0.137. After controlling for pre values, there was not a significant effect of condition on Arms Fat Mass Ratio, $F(2, 28) = 0.65$, p=0.531, $\eta_p^2 < .04$. Estimated marginal means were similar in the HI ($M = .787$, $SE = .015$), HI+AE ($M = .779$, $SE = .015$), and BFR ($M = .803$, $SE = .014$) conditions.

Figure 35. Arms to Fat Mass Ratio

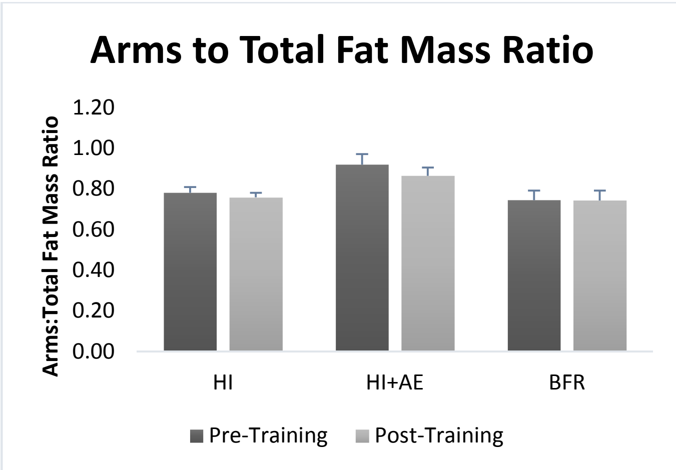


Figure 36 shows the change in estimated visceral adipose tissue (EVAT) from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 36. Estimated Visceral Adipose Tissue

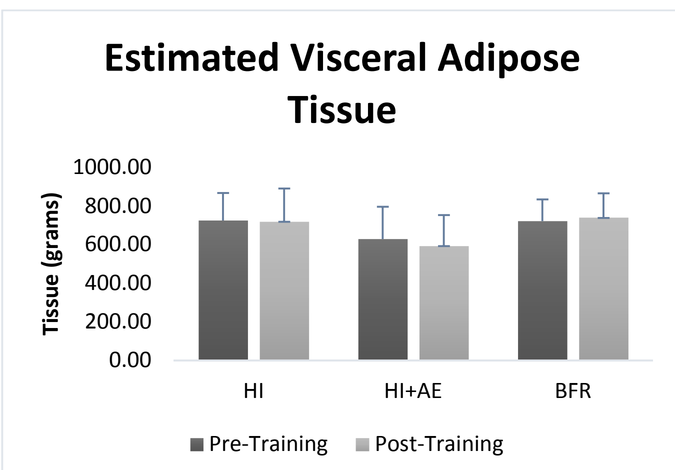
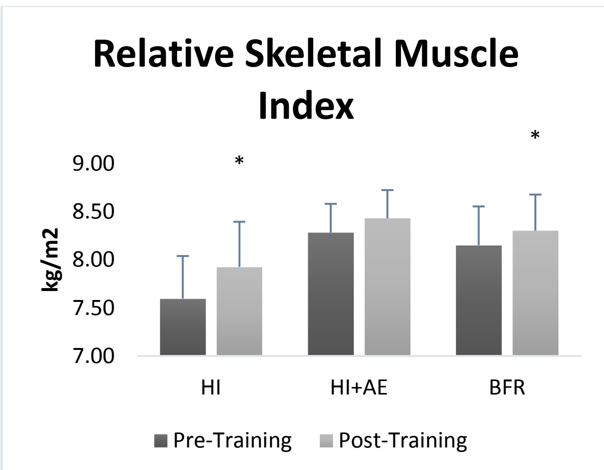
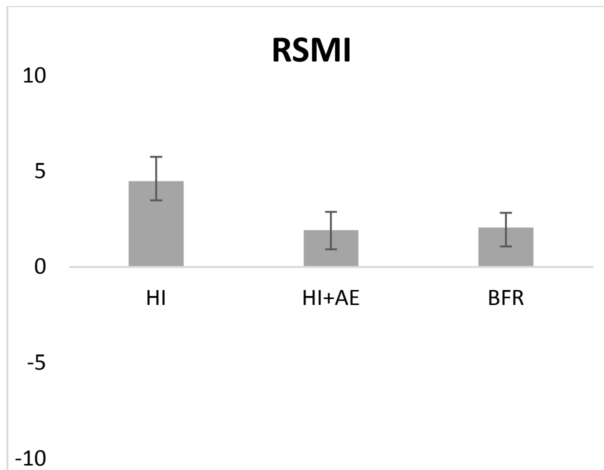


Figure 37a shows the change in relative skeletal muscle index (RSMI) from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect ($p=0.001$), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.008) and BFR (p=0.038) significantly increased from baseline and a trend was seen in HI+AE (p=0.070). Figure 37b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 4.48 %, 1.92 %, and 2.07 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 37a. Relative Skeletal Muscle Index **Figure 37b.** Change in RSMI (%)



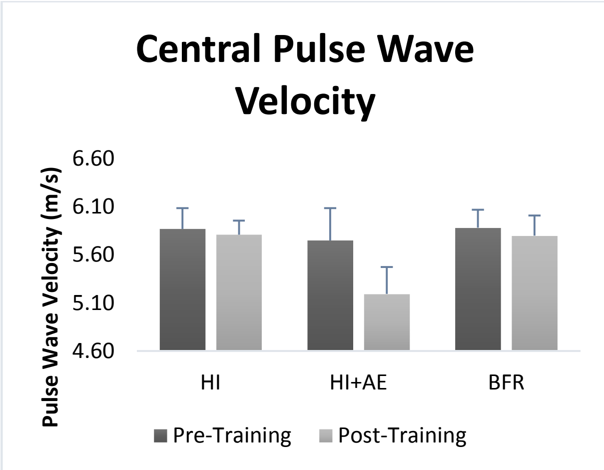


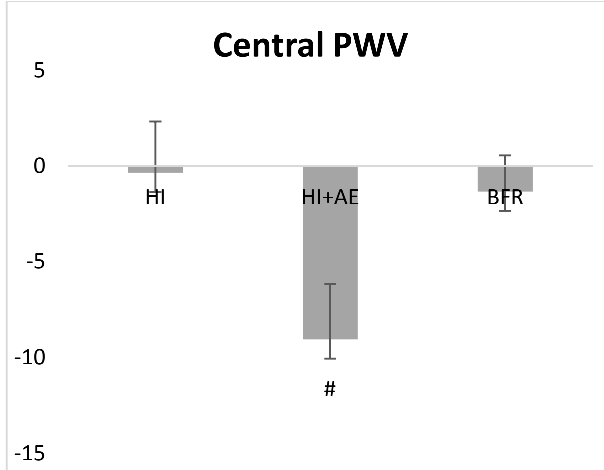
* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Cardiovascular Variables

Figure 38a shows the change in PWV from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions. Figure 38b shows the percent change from pre to post for each condition. A one-way ANOVA found significant difference in percent change between conditions (p=0.040). Percent changes for HI, HI+AE, and BFR were -0.35 %, -9.06 %, and -1.34 %, respectively.

Figure 38a. Pulse Wave Velocity **Figure 38b.** Change in PWV (%)





Significant % Change (p < 0.05) between groups.

Figure 39 shows the change in aortic SBP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 39. Aortic Systolic Blood Pressure

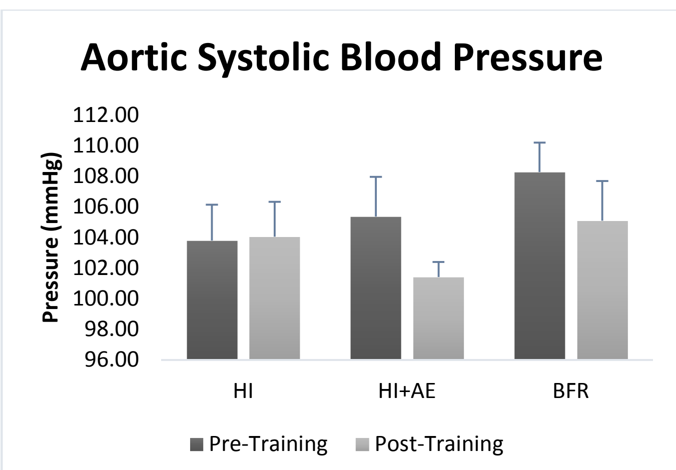
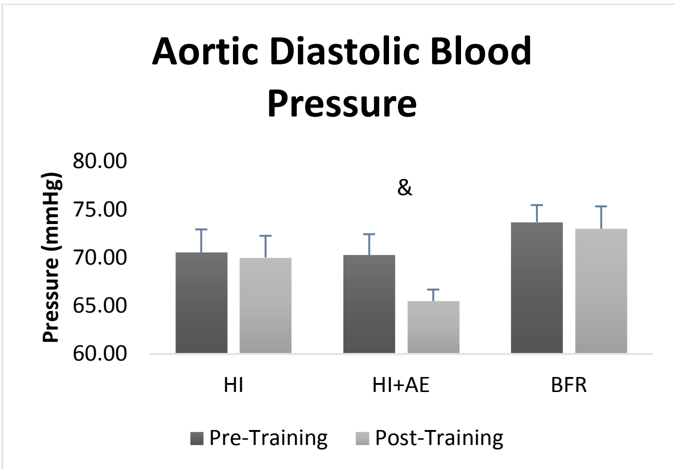


Figure 40 shows the change in aortic DBP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant condition main effect between HI+AE and BFR (p=0.039). No significant time main effect or condition*time interactions were found.

Figure 40. Aortic Diastolic Blood Pressure



& Significant condition main effect between HI+AE and BFR ($p < 0.05$)
Values reported as mean ± SE.

Figure 41 shows the change in aortic PP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 41. Aortic Pulse Pressure

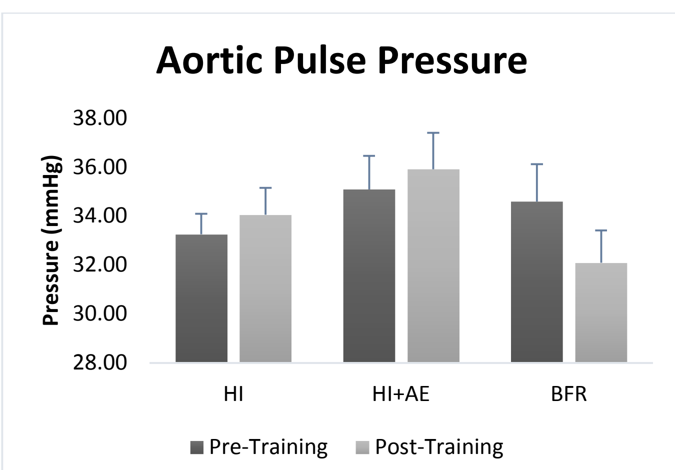


Figure 42a shows the change in aortic MAP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.033), with no significant condition main effect or condition*time interactions. The follow up test showed that HI+AE significantly decreased from baseline (p=0.030). Figure 42b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -1.96 %, -7.80 %, and -3.84 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 42a. Aortic Mean Arterial Pressure

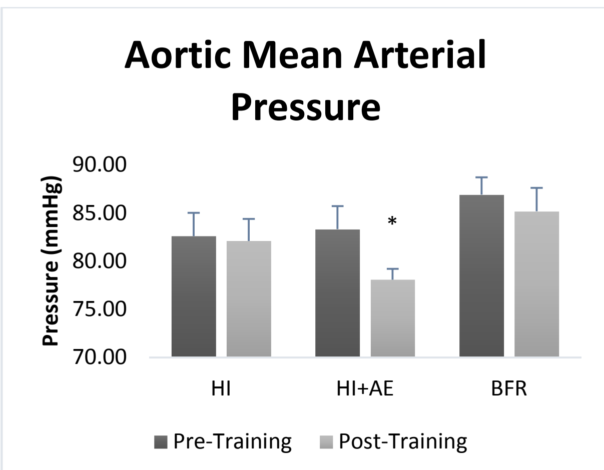
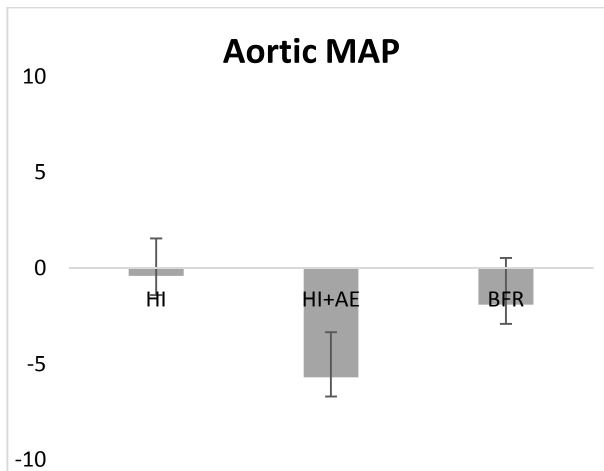


Figure 42b. Change in Aortic MAP (%)



* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 43a shows the change in aortic HR from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect or condition main effect. There was a trend for a condition*time interaction (p=0.061). Figure 43b shows the percent change from pre to post for each condition. A one-way ANOVA found significant difference in percent change between conditions (p=0.050). Percent changes for HI, HI+AE, and BFR were -0.40 %, -5.69 %, and -1.90 %, respectively.

Figure 43a. Aortic Heart Rate

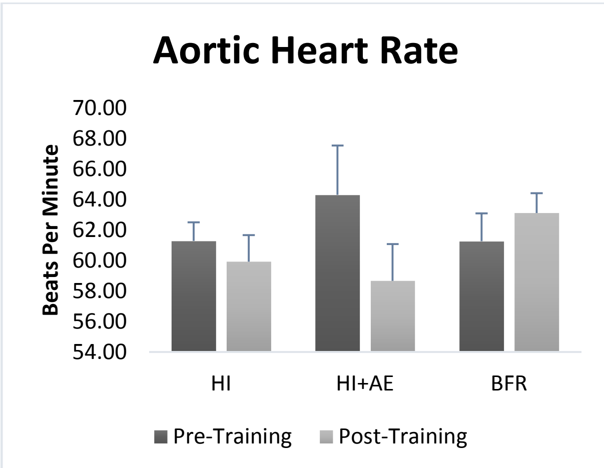
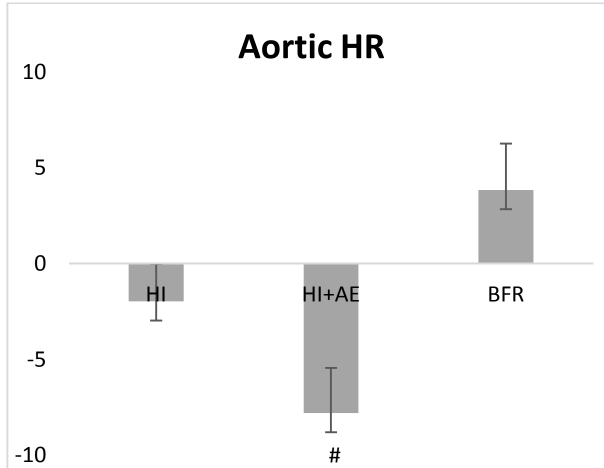


Figure 43b. Change in Aortic HR (%)



Significant % Change (p < 0.05) between groups.

Figure 44 shows the change in brachial systolic blood pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 44. Brachial Systolic Blood Pressure

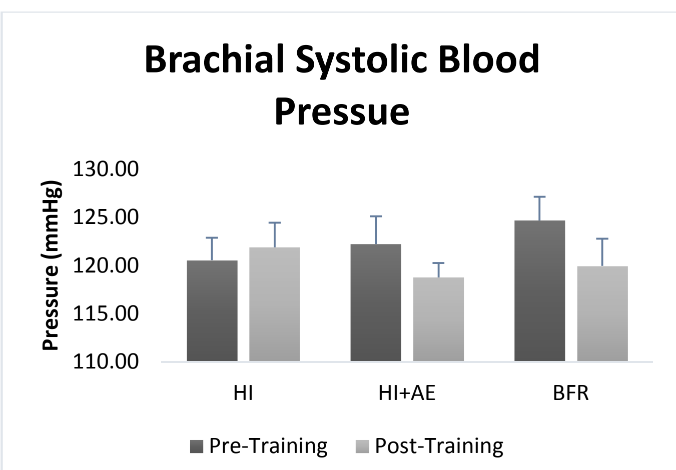
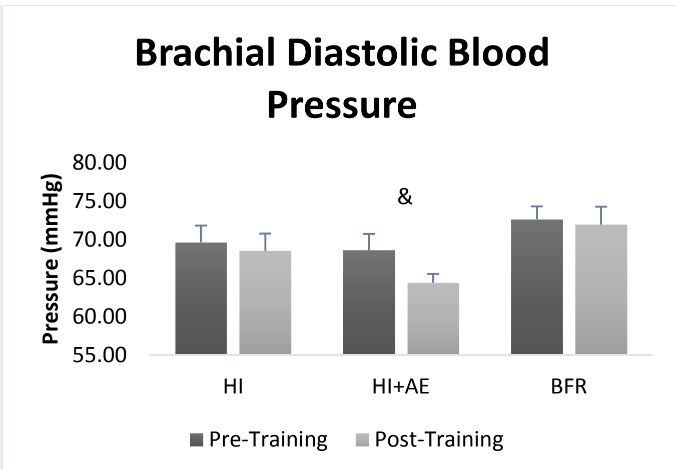


Figure 45 shows the change in brachial DBP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant condition main effect between HI+AE and BFR (p=0.025). No significant time main effect or condition*time interactions were found.

Figure 45. Brachial Diastolic Blood Pressure



& Significant condition main effect between HI+AE and BFR ($p < 0.05$)
Values reported as mean ± SE.

Figure 46 shows the change in aortic augmentation index from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 46. Aortic Augmentation Index

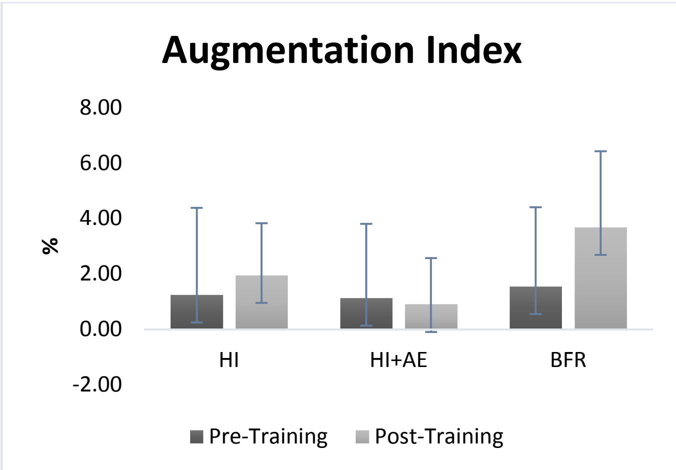


Figure 47 shows the change in aortic augmentation index @ HR75 from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect or condition main effect. There was a trend for a condition*time interaction (p=0.061).

Figure 47. Augmentation Index @ HR75

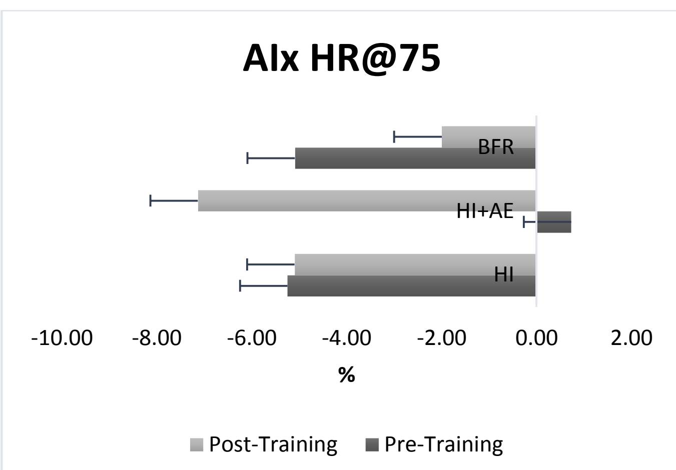


Figure 48a shows the change in HR period from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect or condition main effect, but there was a condition*time interaction (p=0.035). Figure 52b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 2.36 %, 10.18 %, and -3.49 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 48a. Heart Rate Period

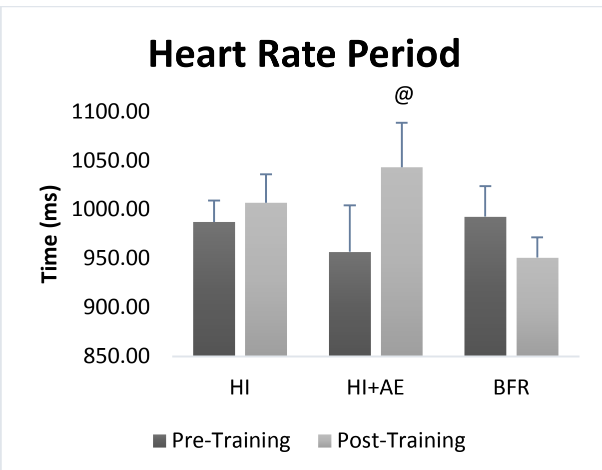
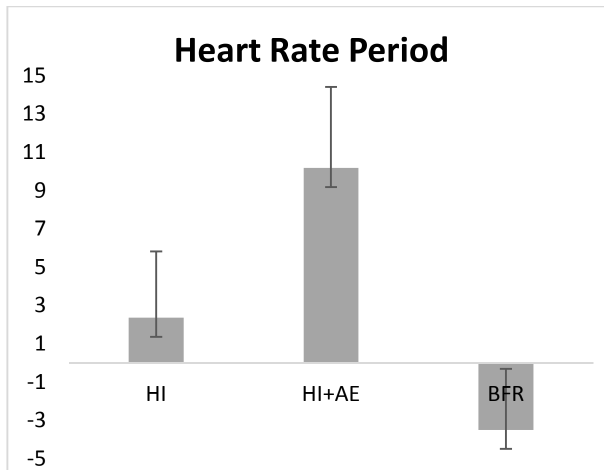


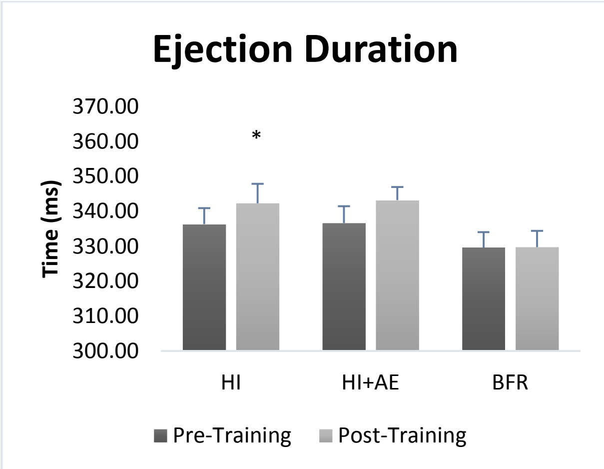
Figure 48b. Change in HR Period (%)

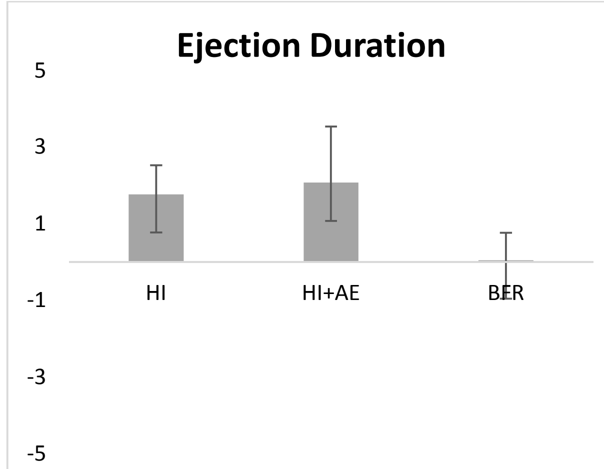


@ Significant time*condition interaction (p < 0.05).
Values reported as mean ± SE.

Figure 49a shows the change in ejection duration from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.042), with no significant condition main effect or condition*time interactions. The follow up test showed that significant increases from baseline were found in the HI condition (p=0.039). Figure 49b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -1.77%, -2.08 %, and 0.04 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 49a. Ejection Duration **Figure 49b.** Change in Ejection Duration (%)





* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 50 shows the change in aortic T2 from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 50. Aortic T2

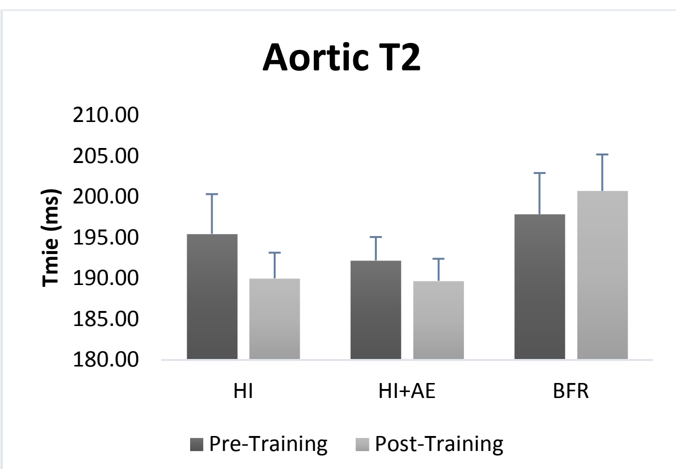


Figure 51a shows the change in aortic P1 height from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences.

No significant differences were noted, but a trend was seen between conditions (p=0.068). Figure 51b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 3.71 %, 4.89 %, and -7.05 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 51a. P1 Height

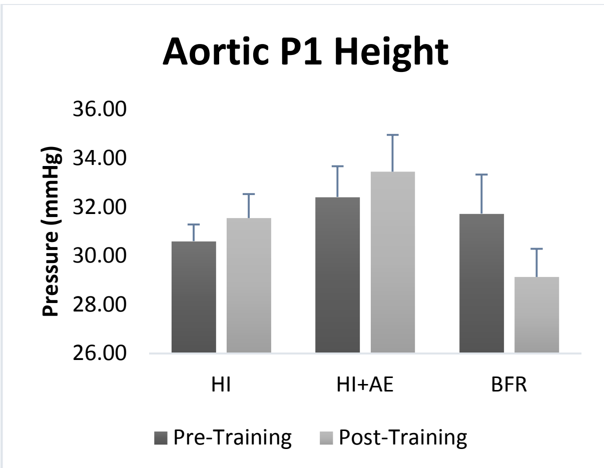


Figure 51b. Change in P1 Height (%)

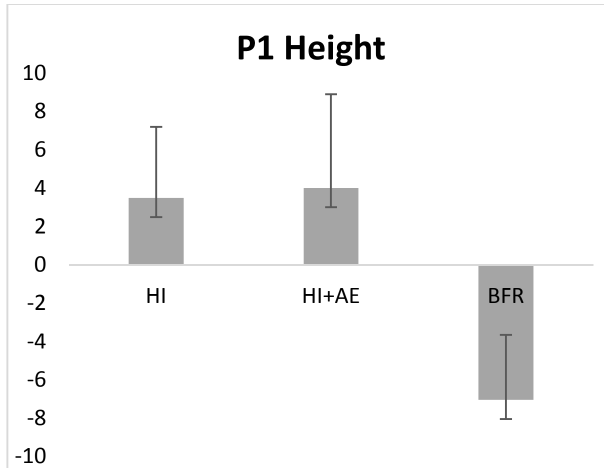


Figure 52 shows the change in augmentation pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effects, condition main effect or condition*time interactions.

Figure 52. Augmentation Pressure

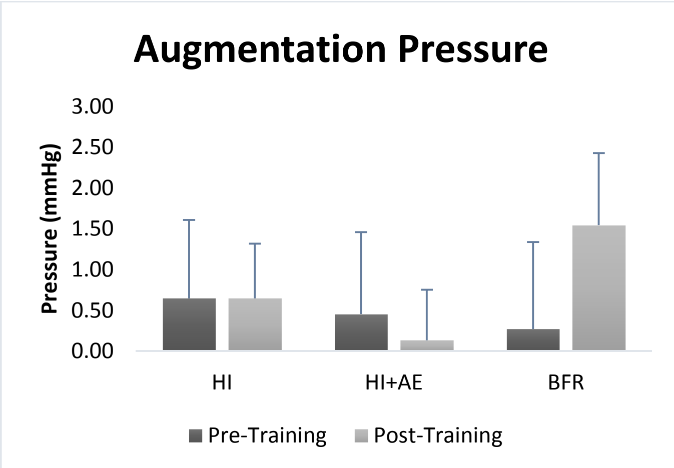


Figure 53 shows the change in Buckberg SEVR from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 53. Buckberg SEVR

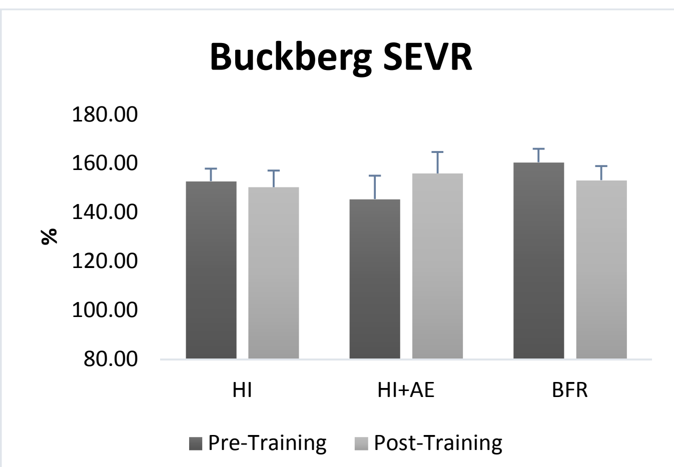


Figure 54a shows the change in end systolic pressure from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted, but a trend was seen between conditions (p=0.069). Figure 54b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were -0.91 %, -6.0 %, and -2.03%, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 54a. End Systolic Pressure

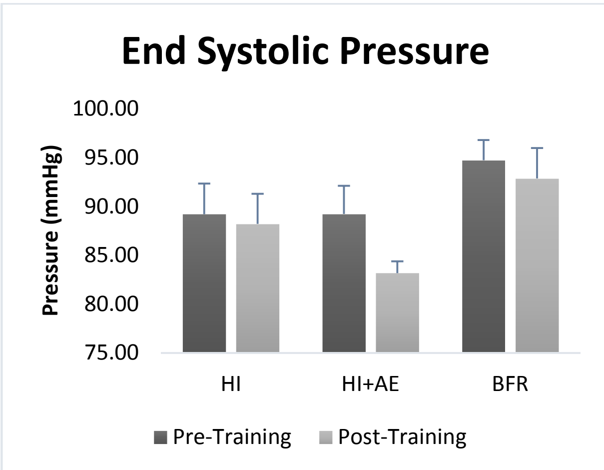


Figure 54b. Change in ESP (%)

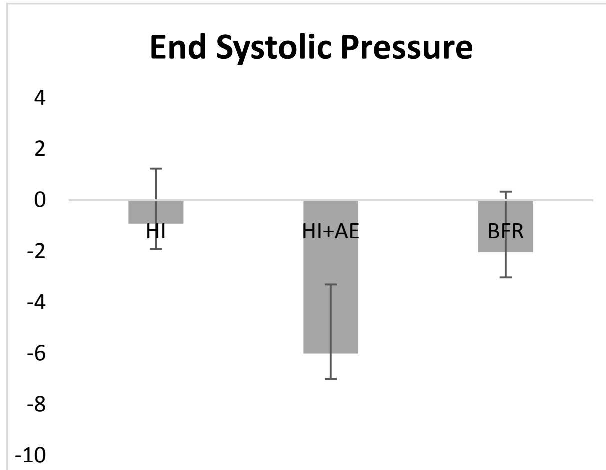


Figure 55 shows the change in forward pulse height from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 55. Forward Pulse Height

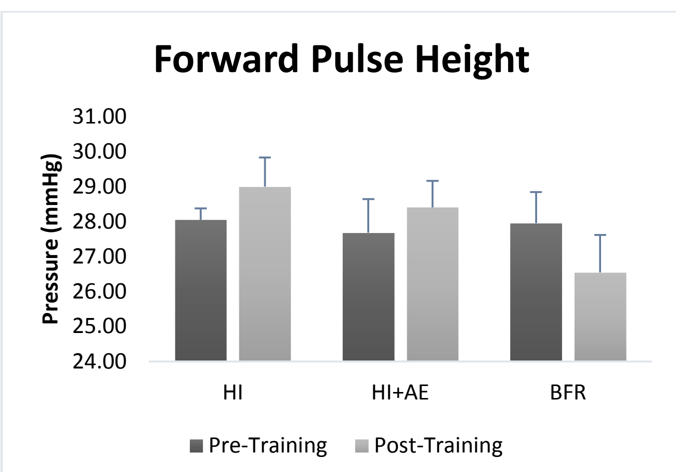


Figure 56 shows the change in reflected pulse height from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 56. Reflected Pulse Height

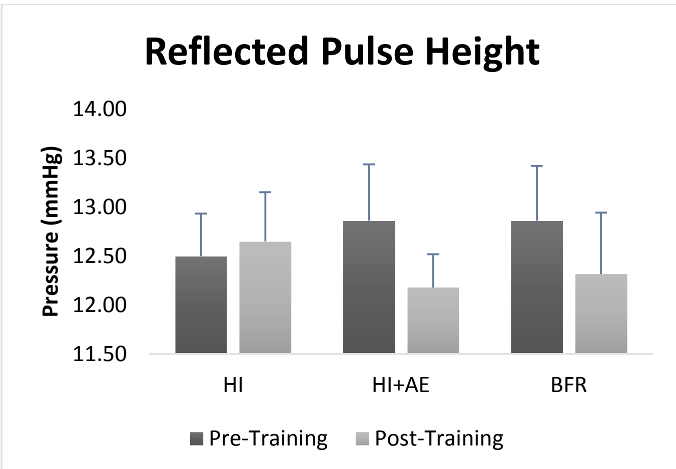
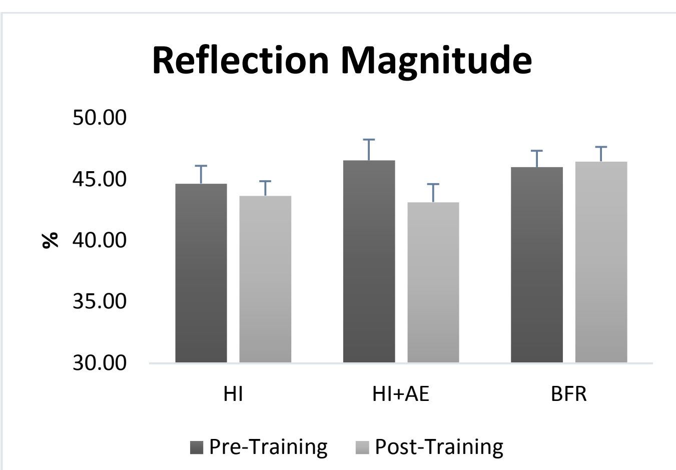


Figure 57 shows the change in reflection magnitude from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 57. Reflection Magnitude



Strength Measures

Figure 58a shows the change in legs press one repetition maximum (1RM) from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.01), HI+AE (p=0.01), and BFR (p=0.01) significantly increased from baseline to post-training. Figure 58b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 65.06 %, 47.54 %, and 55.98 %, respectively.

Figure 58a. Leg Press 1RM

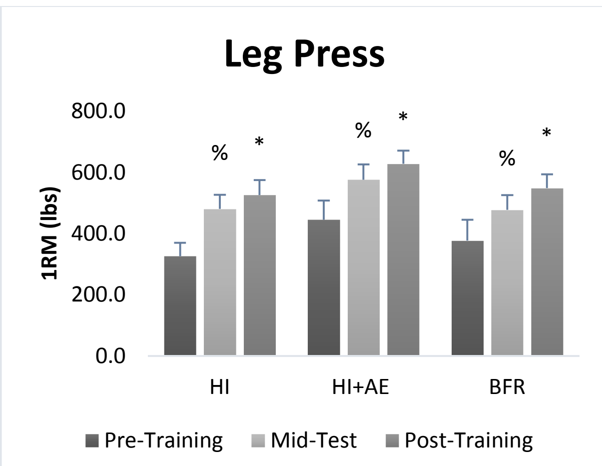
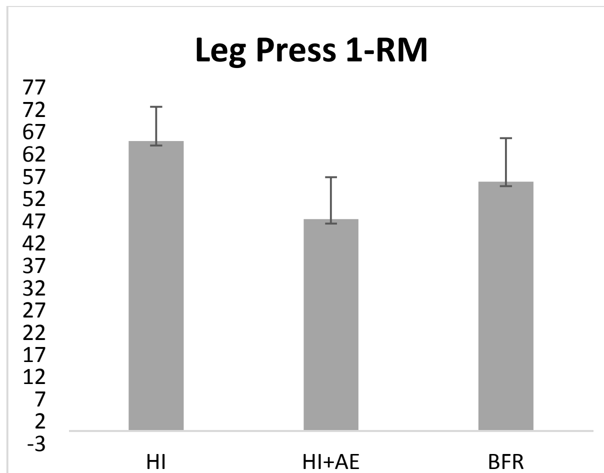


Figure 58b. Change in Leg Press 1RM (%)



% Significant difference ($p < 0.05$) from pre- to mid-training.
* Significant difference ($p < 0.05$) from mid- to post-training.
Values reported as mean ± SE.

Figure 59a shows the change in legs extension 1RM from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions. The follow up test showed that HI (p=0.01), HI+AE (p=0.01), and BFR (p=0.01) significantly increased from baseline to post-training. Figure 59b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 60.13 %, 61.31 %, and 45.58 %, respectively.

Figure 59a. Leg Extension 1RM

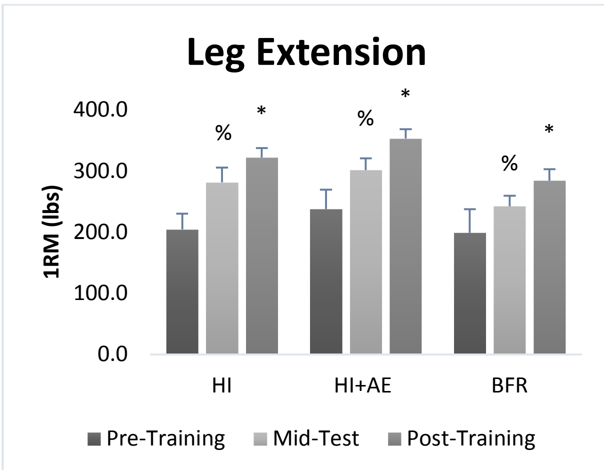
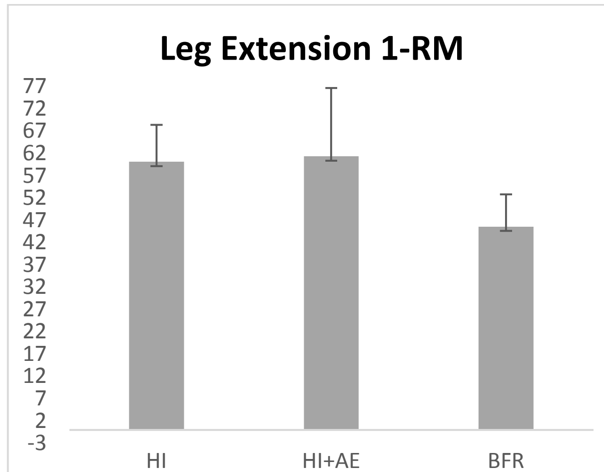


Figure 59b. Change in Leg Extension 1RM (%)



% Significant difference ($p < 0.05$) from pre- to mid-training.
* Significant difference ($p < 0.05$) from mid- to post-training.
Values reported as mean ± SE.

Figure 60a shows the change in legs curl 1RM from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions. The follow up test showed that HI (p=0.01), HI+AE (p=0.01), and BFR (p=0.01) significantly increased from baseline to post-training. Figure 60b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 28.98 %, 34.31 %, and 19.52 %, respectively.

Figure 60a. Leg Curl 1RM

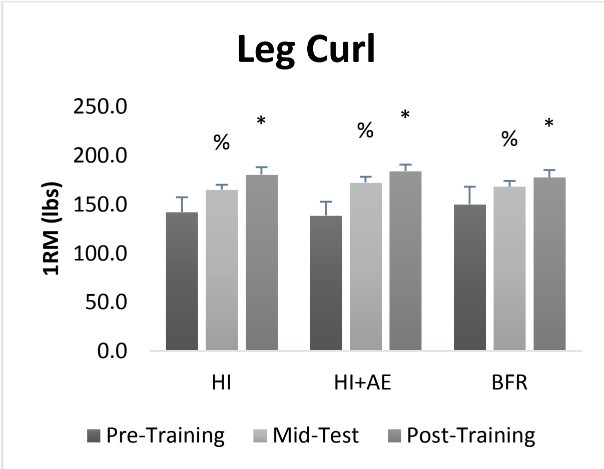
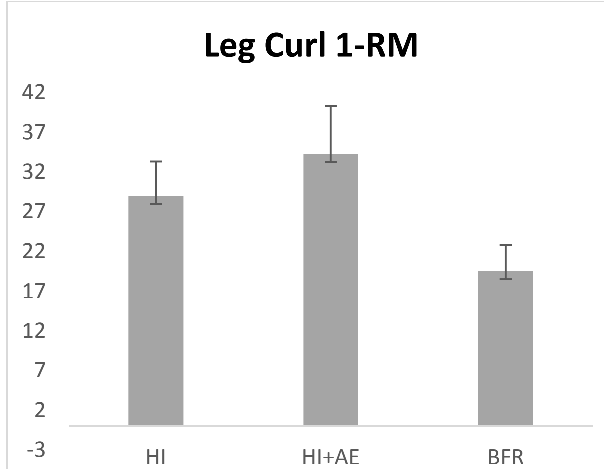


Figure 60b. Change in Leg Curl 1RM (%)



% Significant difference (p < 0.05) from pre- to mid-training.
* Significant difference (p < 0.05) from mid- to post-training.
Values reported as mean ± SE.

Figure 61a shows the change in incline bench press 1RM from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.01), HI+AE (p=0.01), and BFR (p=0.01) significantly increased from baseline to post-training. Figure 61b shows the percent change from pre to post for each condition. A one-way ANOVA found significant difference in percent change between conditions (p=0.015). Percent changes for HI, HI+AE, and BFR were 32.58 %, 16.78 %, and 15.56 %, respectively.

Figure 61a. Incline Bench Press 1RM

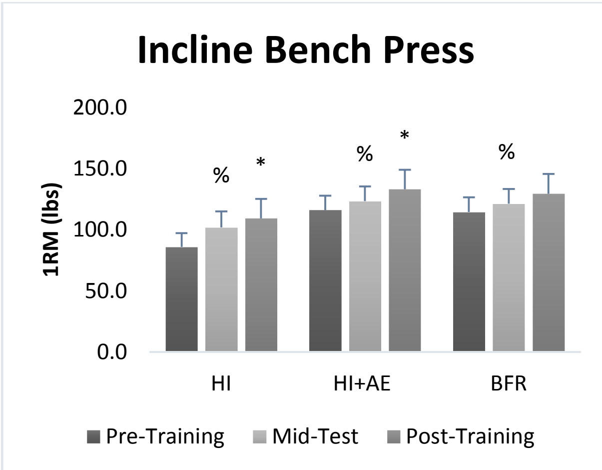
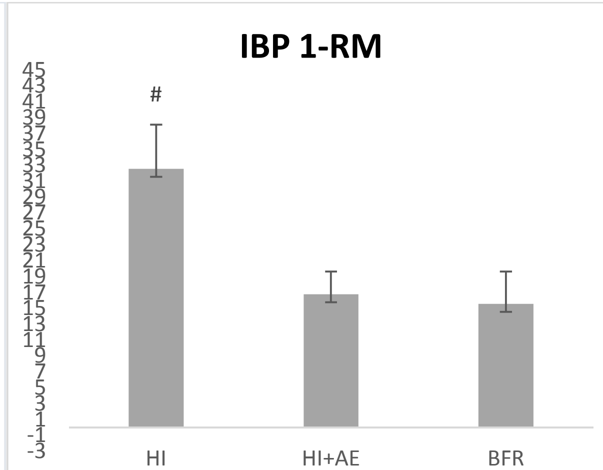


Figure 61b. Change in IBP 1RM (%)



% Significant difference ($p < 0.05$) from pre- to mid-training.
* Significant difference ($p < 0.05$) from mid- to post-training.
Values reported as mean ± SE.

Significant % Change ($p < 0.05$) between groups.

Figure 62a shows the change in lat pulldown 1RM from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no condition*time interactions. The follow up test showed that HI (p=0.01), HI+AE (p=0.01), and BFR (p=0.01) significantly increased from baseline to post-training. Figure 62b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 22.46 %, 20.34 %, and 15.30 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 62a. Lat Pulldown 1RM

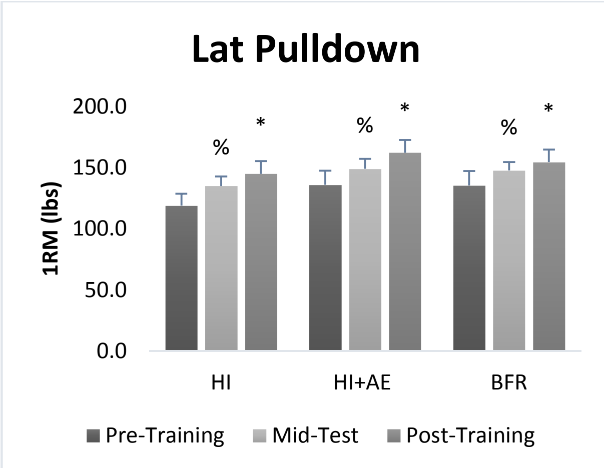


Figure 62b. Change in Lat Pulldown 1RM (%)

% Significant difference ($p < 0.05$) from pre- to mid-training.
* Significant difference ($p < 0.05$) from mid- to post-training.
Values reported as mean ± SE.

Figure 63a shows the change in shoulder press 1RM from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.029), HI+AE (p=0.01), and BFR (p=0.01) significantly increased from baseline to post-training. Figure 63b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 21.61 %, 24.07 %, and 15.61 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 63a. Shoulder Press 1RM

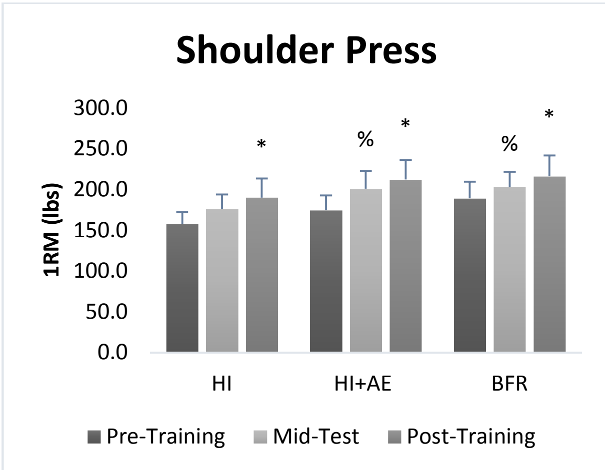
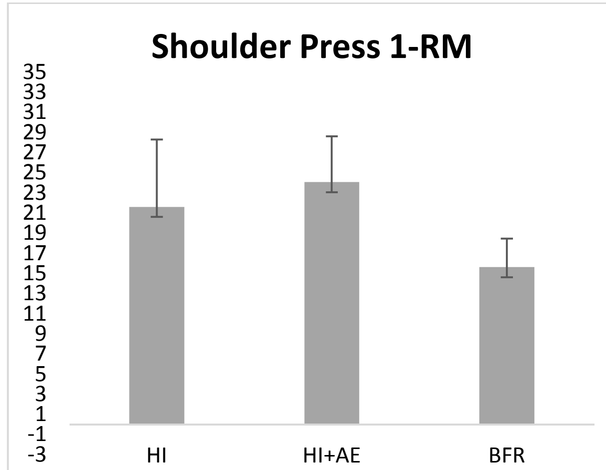


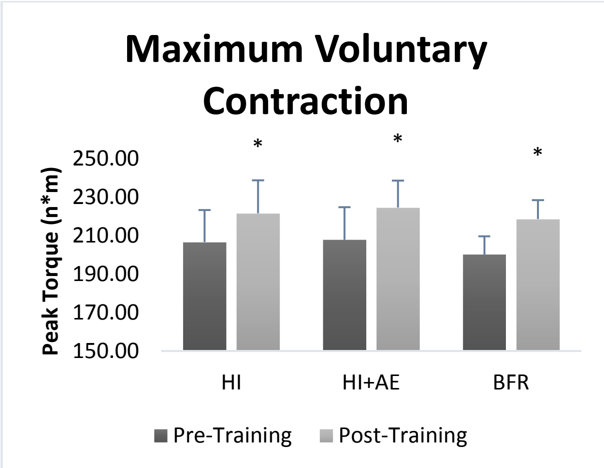
Figure 63b. Change in Shoulder Press 1RM (%)

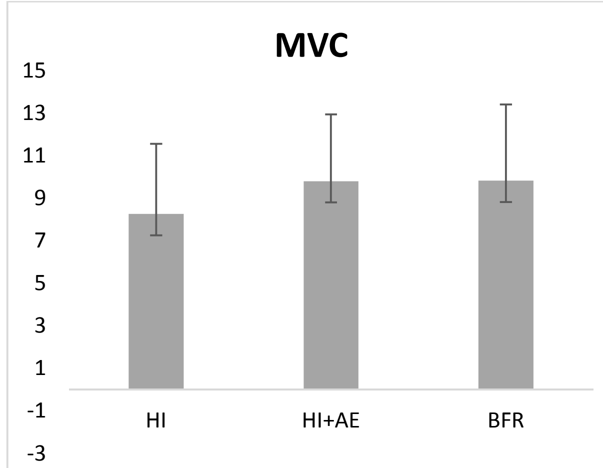


% Significant difference (p < 0.05) from pre- to mid-training.
* Significant difference (p < 0.05) from mid- to post-training.
Values reported as mean ± SE.

Figure 64a shows the change in maximum voluntary contraction (MVC) from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.046), HI+AE (p=0.005), and BFR (p=0.001) significantly increased from baseline to post-training. Figure 64b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 8.26 %, 9.80 %, and 9.82 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 64a. Maximum Voluntary Contraction **Figure 64b.** Change in MVC (%)

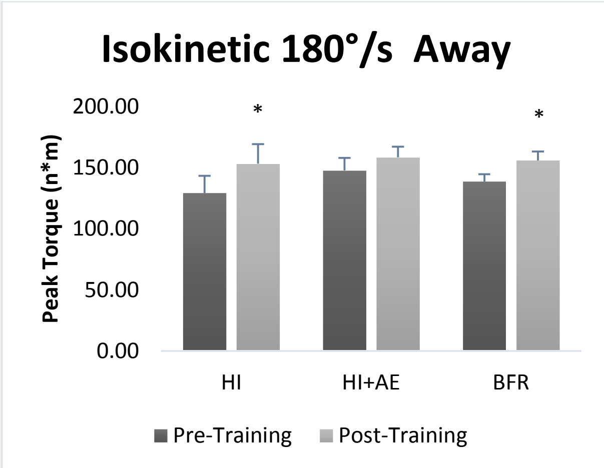




* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 65a shows the change in isokinetic 180°/s away (ISO 180) from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect ($p < 0.001$), with no significant condition main effect or condition*time interactions. The follow up test showed that HI ($p=0.029$) and BFR ($p=0.001$) significantly increased from baseline, and a trend was seen for HI+AE ($p=0.057$). Figure 65b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 20.49 %, 9.18 %, and 12.97 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 65a. ISO 180 Away



* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 65b. Change in ISO 180 Away (%)

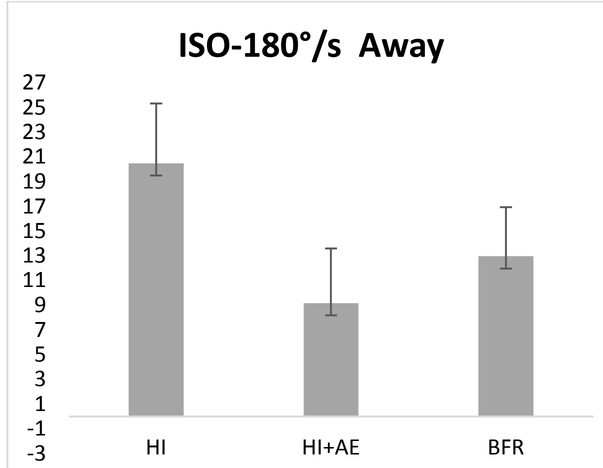
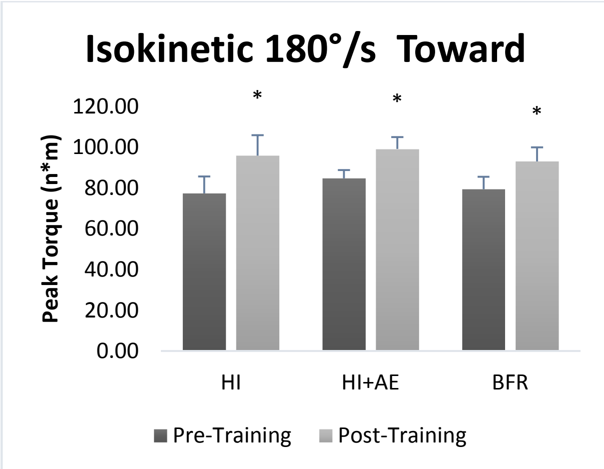


Figure 66a shows the change in isokinetic 180°/s toward from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.007), HI+AE (p=0.015), and BFR (p=0.010) significantly increased from baseline. Figure 66b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 26.62 %, 17.52 %, and 18.66 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 66a. ISO 180 Toward



* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 66b. Change in ISO 180 Toward (%)

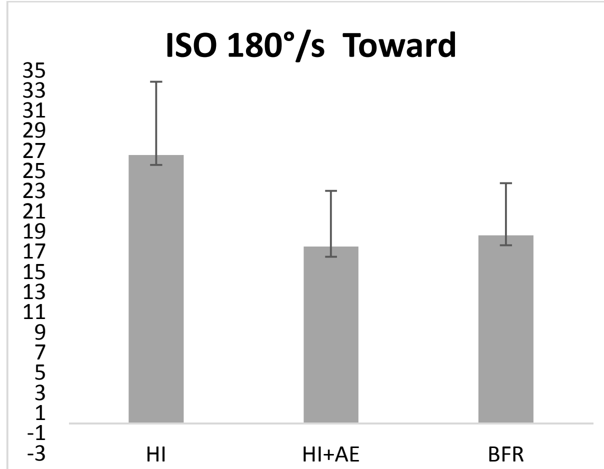


Figure 67 shows the change in ISO 60°/s away from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 67. ISO 60°/s Away

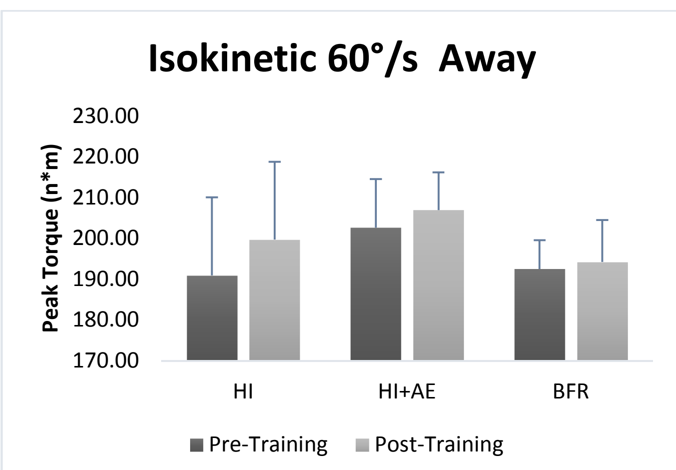


Figure 68 shows the change in isokinetic 60°/s toward from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 68. ISO 60°/s Toward

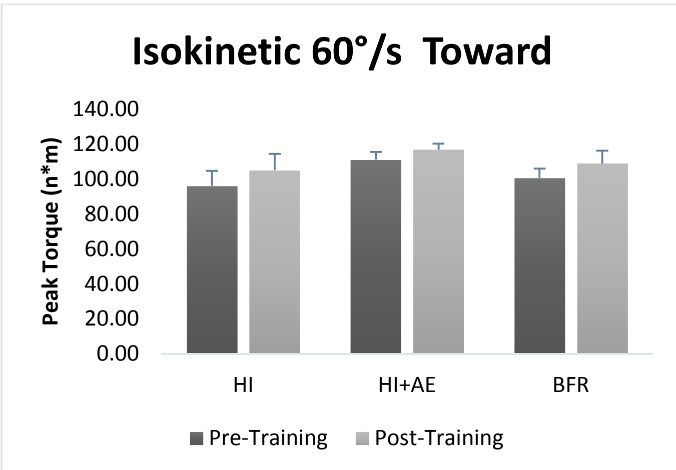


Figure 69 shows the change in the first repetitions of the Thorstensson test from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 69. Thorstensson Beginning

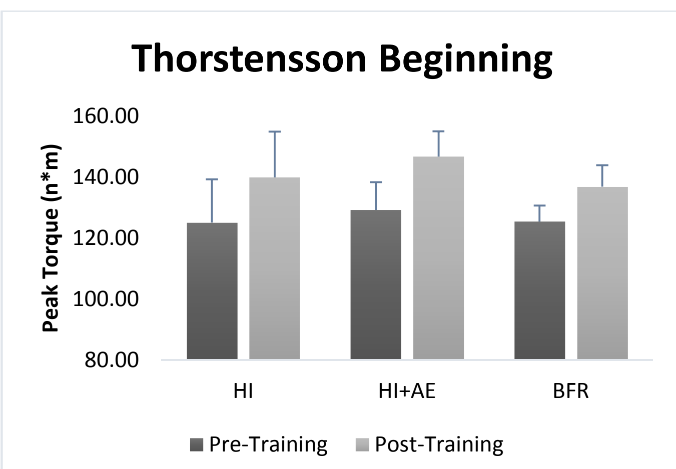
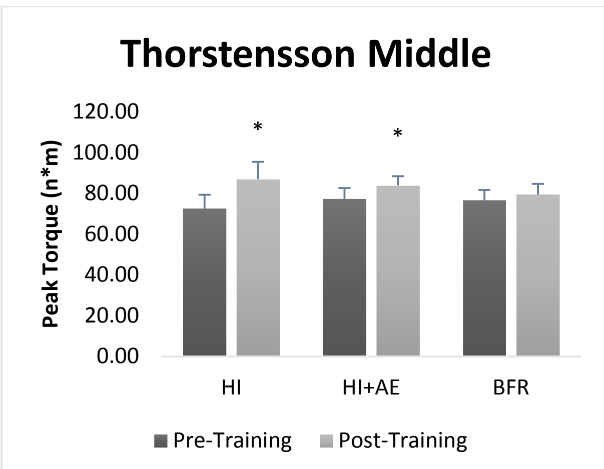
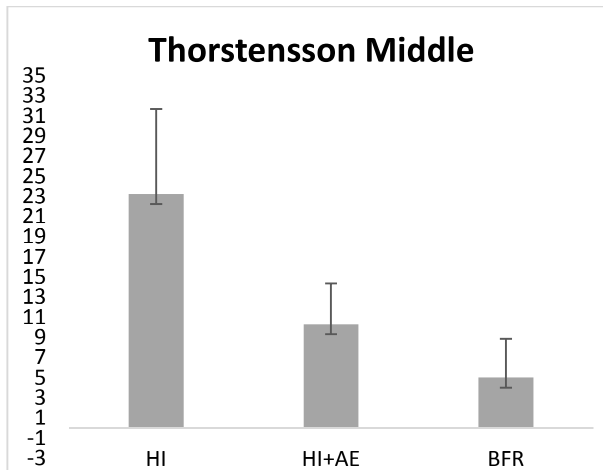


Figure 70a shows the change in repetitions 24, 25, and 26 of the Thorstensson test from pre- to post-training. One-way ANOVA found no significant baseline differences.

Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.001), with no significant condition main effect or condition*time interactions. The follow up test showed that HI (p=0.021) and HI+AE (p=0.025) significantly increased from baseline. Figure 70b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 20.49 %, 9.18 %, and 12.97 %, respectively. No significant difference in % change was noted between conditions (p > 0.05).

Figure 70a. Thorstensson Middle **Figure 70b.** Change in Thorstensson Middle (%)





* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

Figure 71 shows the change in the last three repetitions of the Thorstensson test from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 71. Thorstensson End

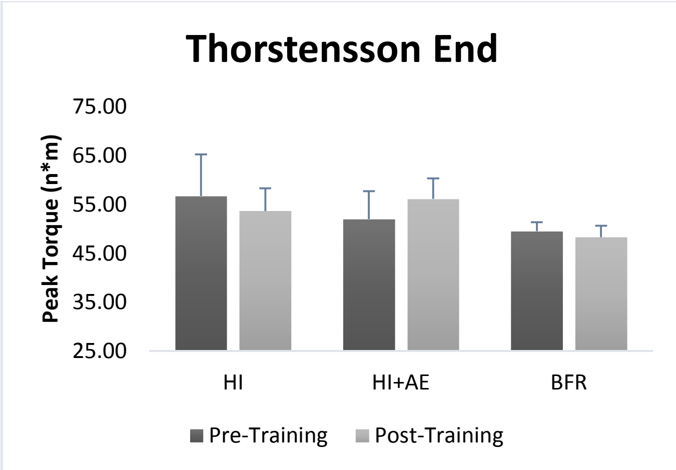


Figure 72 shows the change in the force percent decline in the Thorstensson test from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 72. % Decline

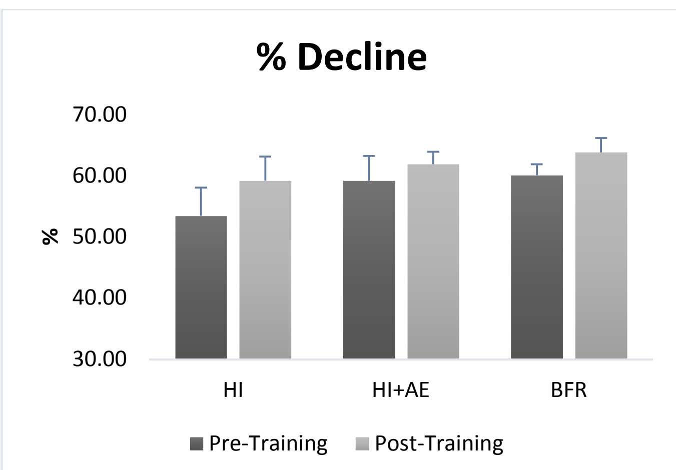


Figure 73 shows the change in fast twitch fiber percentage from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 73. Fast Twitch Fibers %

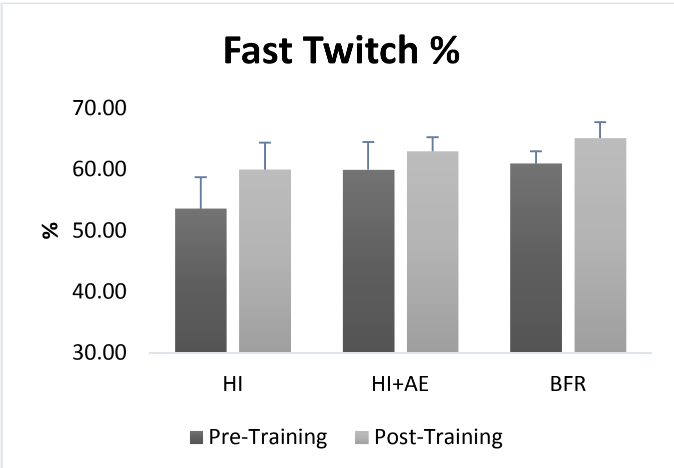
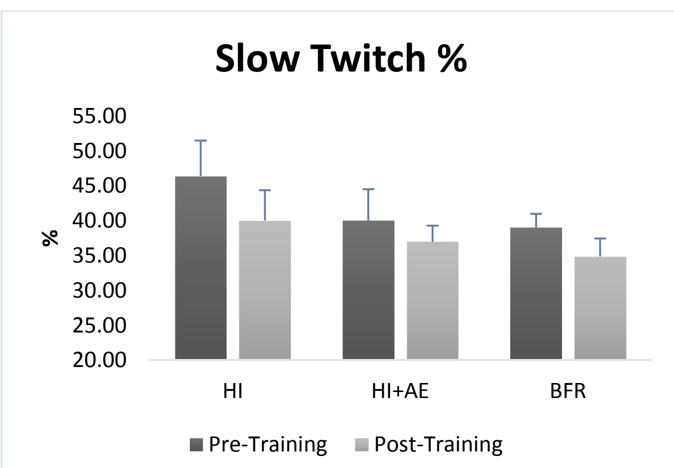


Figure 74 shows the change in slow twitch fiber percentage from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

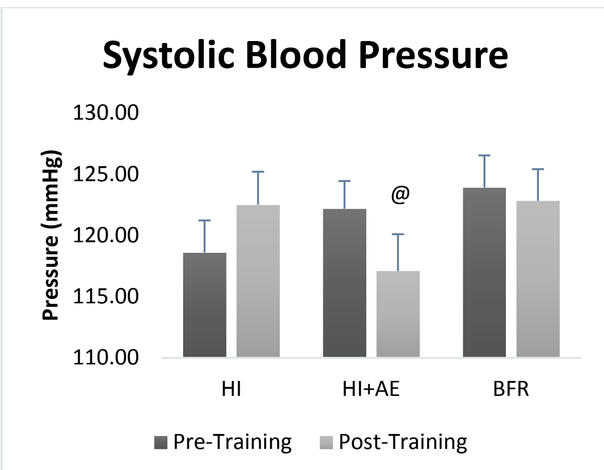
Figure 74. Slow Twitch Fibers %



Hemodynamic Responses

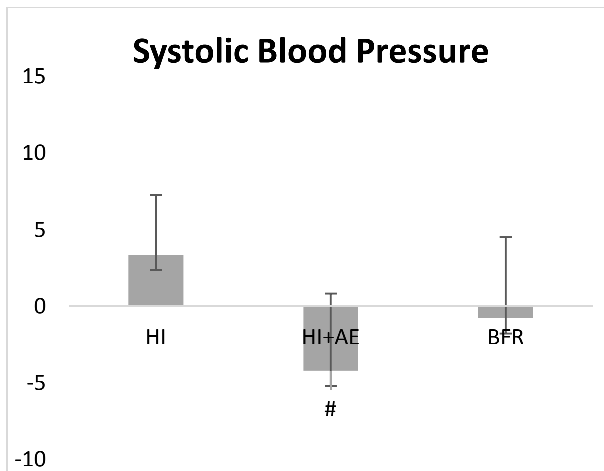
Figure 75a shows the change in HDI SBP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect or condition main effect, but there was a condition*time interaction (p=0.003). Figure 75b shows the percent change from pre to post for each condition. A one-way ANOVA found significant difference in percent change between conditions (p=0.002). Percent changes for HI, HI+AE, and BFR were 3.26 %, -4.21 %, and -0.78 %, respectively.

Figure 75a. Systolic Blood Pressure



@ Significant time*condition interaction (p < 0.05).
Values reported as mean ± SE.

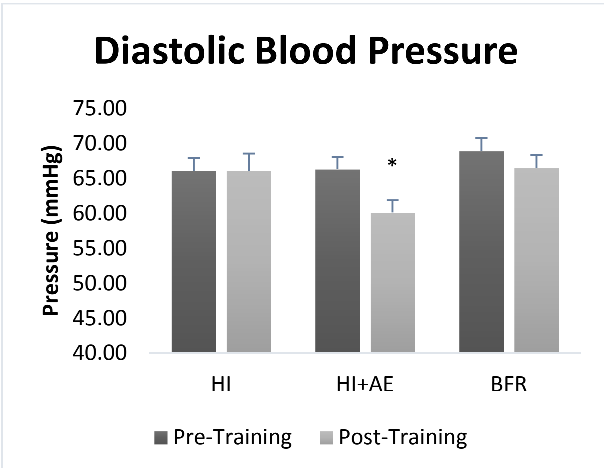
Figure 75b. Change in SBP (%)



Significant % Change (p < 0.05) between groups.

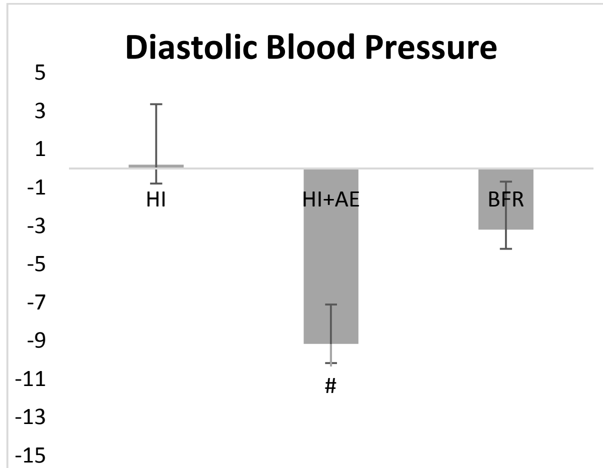
Figure 76a shows the change in HDI DBP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.008) and trend for a condition*time interaction (p=0.054). No significant condition main effect was detected. The follow up test showed that HI+AE (p=0.002) significantly decreased from baseline Figure 76b shows the percent change from pre to post for each condition. A one-way ANOVA found significant difference in percent change between conditions (p=0.049). Percent changes for HI, HI+AE, and BFR were 0.21 %, -9.15 %, and -3.20 %, respectively.

Figure 76a. Diastolic Blood Pressure



* Significantly different (p < 0.05) from baseline.
Values reported as mean ± SE.

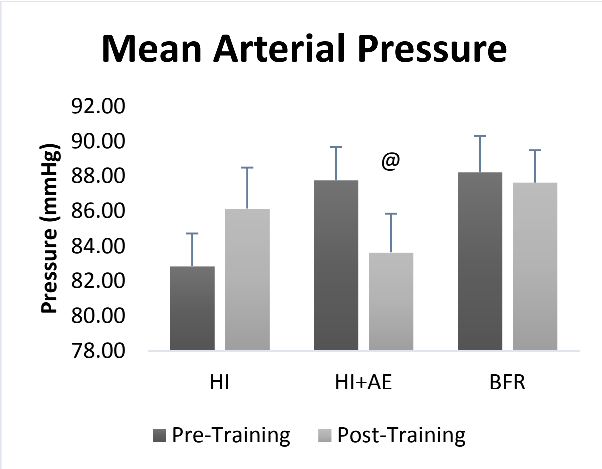
Figure 76b. Change in DBP (%)

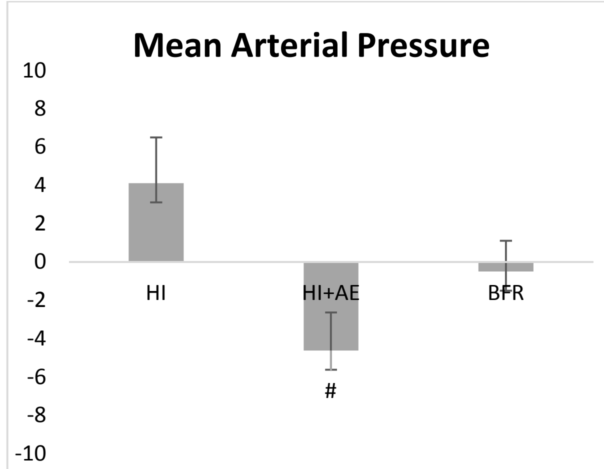


Significant % Change (p < 0.05) between groups.

Figure 77a shows the change in HDI MAP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect or condition main effect, but there was a condition*time interaction (p=0.018). The follow up test showed that HI+AE significantly decreased from baseline (p=0.002). Figure 77b shows the percent change from pre to post for each condition. A one-way ANOVA found significant difference in percent change between conditions (p=0.017). Percent changes for HI, HI+AE, and BFR were 4.11 %, -4.62 %, and -0.50 %, respectively.

Figure 77a. Mean Arterial Pressure **Figure 77b.** Change in MAP (%)



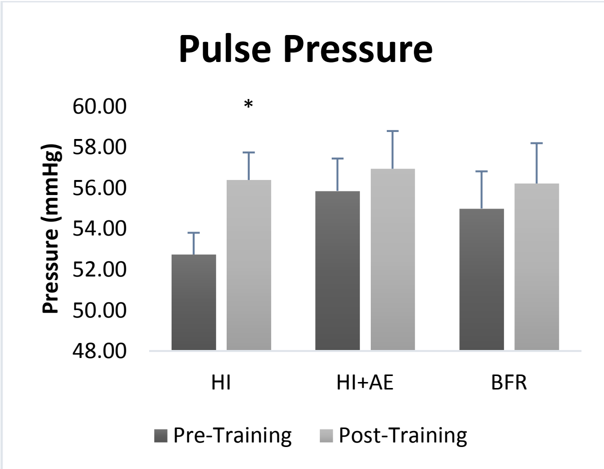


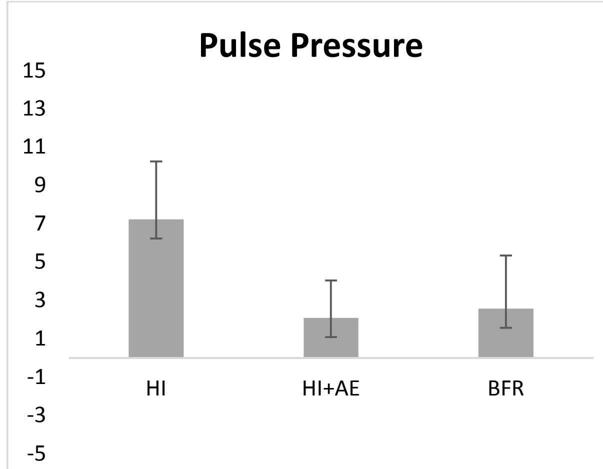
@ Significant time*condition interaction ($p < 0.05$). Values reported as mean ± SE.

Significant % Change ($p < 0.05$) between groups.

Figure 78a shows the change in HDI PP from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.02), with no significant condition main effect or condition*time interactions. The follow up test showed that HI significantly increased from baseline (p=0.043). Figure 78b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 7.22 %, 2.08 %, and 2.56 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 78a. Pulse Pressure **Figure 78b.** Change in PP (%)

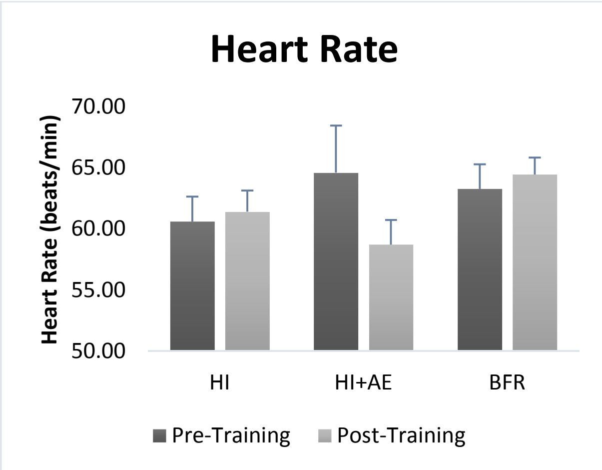




* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 79a shows the change in HDI HR from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect or condition main effect, but there was a trend for a condition*time interaction (p=0.063). Figure 79b shows the percent change from pre to post for each condition. A one-way ANOVA found a trend in percent change between conditions (p=0.051).Percent changes for HI, HI+AE, and BFR were 4.11 %, -4.62 %, and -0.50 %, respectively.

Figure 79a. Heart Rate **Figure 79b.** Change in HR (%)



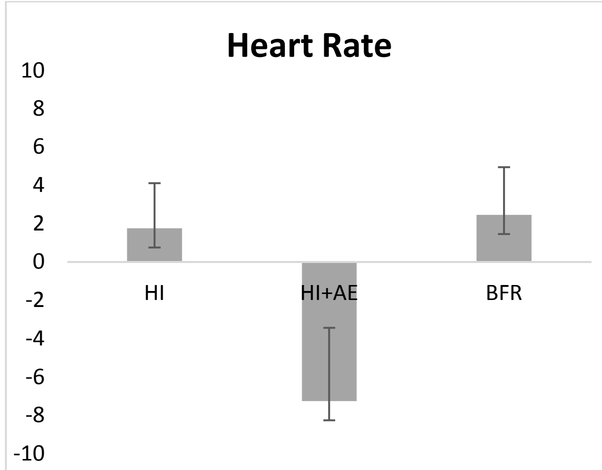


Figure 80a shows the change in HDI CET time from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.028), with no significant condition main effect or condition*time interactions. The follow up test showed that HI+AE significantly increased from baseline (p=0.017). Figure 80b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 0.94 %, 6.63 %, and 1.35 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 80a. Cardiac Ejection Time

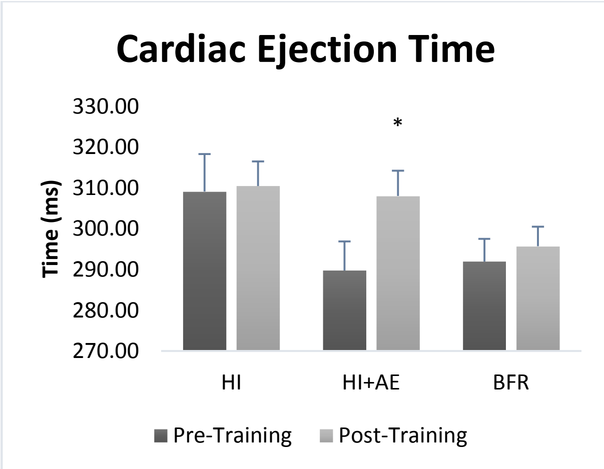
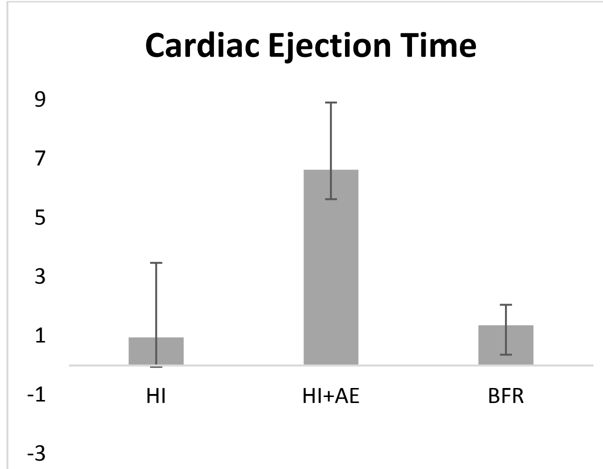


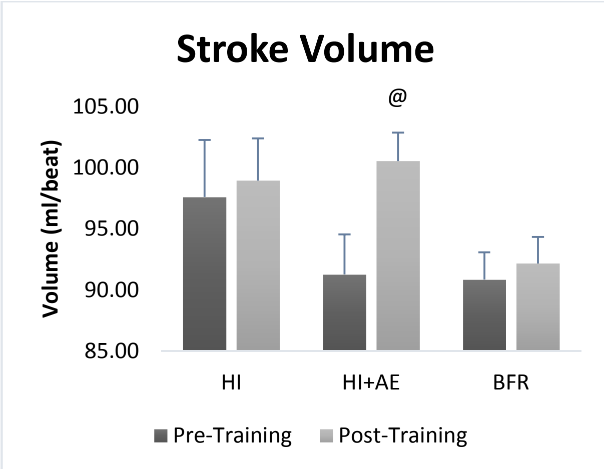
Figure 80b. Change in CET (%)

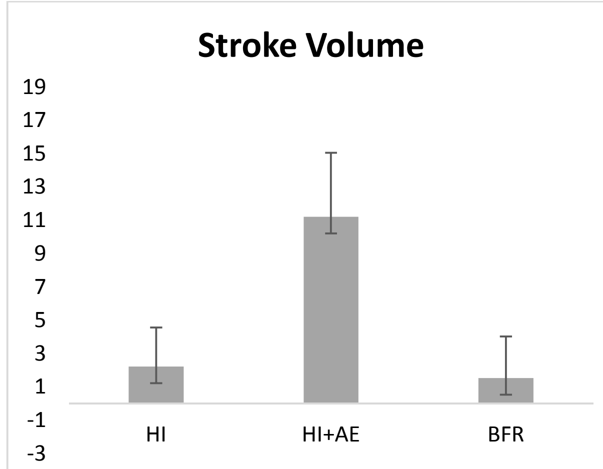


* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 81a shows the change in HDI SV from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect (p=0.010) and significant condition*time interaction (p=0.046). The follow up test showed that HI+AE significantly increased from baseline (p=0.010). Figure 81b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 2.22 %, 11.22 %, and 1.53 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 81a. Stroke Volume **Figure 81b.** Change in SV (%)





@ Significant time*condition interaction ($p < 0.05$).
Values reported as mean ± SE.

Figure 82 shows the change in HDI SVI from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 82. Stroke Volume Index

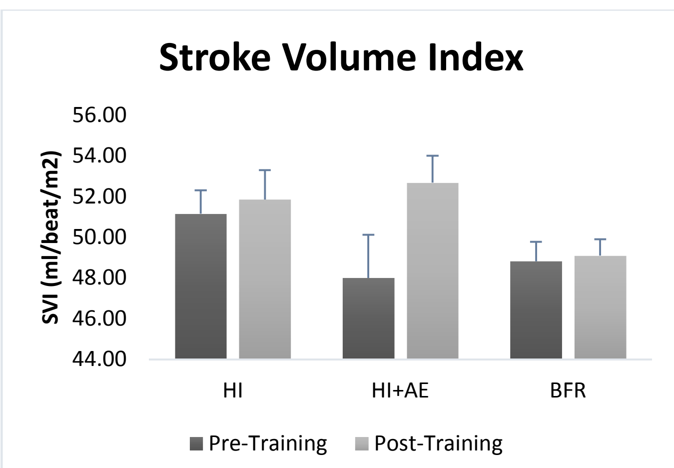


Figure 83 shows the change in CO from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was not met by Levene's test, therefore a Kruskal-Wallis test was performed to find any condition differences. No significant differences were noted between conditions.

Figure 83. Cardiac Output

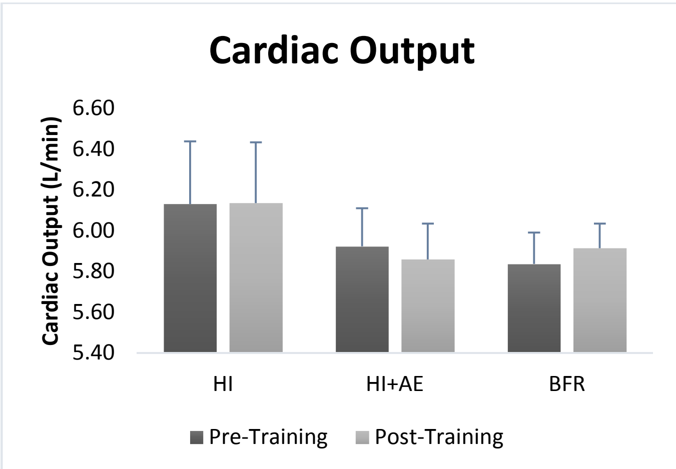


Figure 84 shows the change in CI from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 84. Cardiac Index

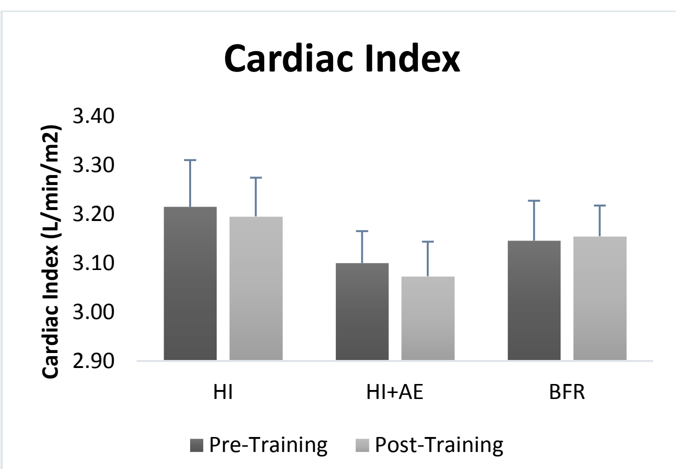
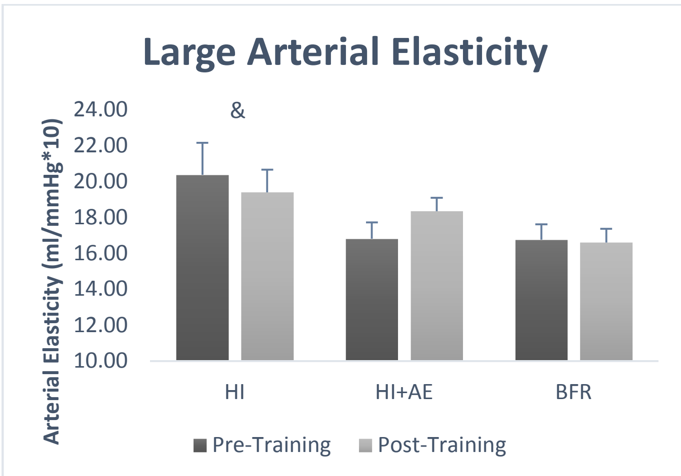


Figure 85 shows the change in LAE from pre to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test.

A two-way ANOVA with repeated measures detected a significant condition main effect between HI and BFR (p=0.033). No significant time main effect or condition*time interactions were found.

Figure 85. Large Arterial Elasticity



& Significant condition main effect between HI and BFR ($p < 0.05$).
Values reported as mean ± SE.

Figure 86 shows the change in SAE from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 86. Small Arterial Elasticity

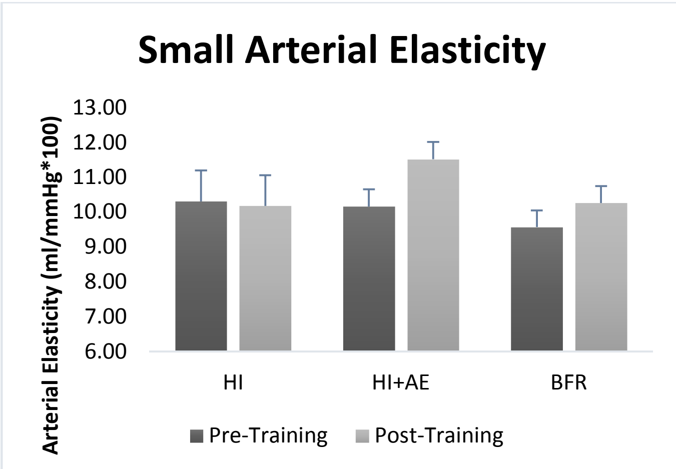
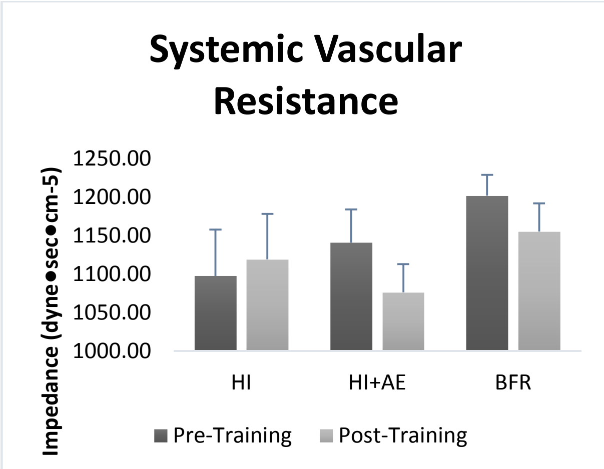


Figure 87a shows the change in HDI SVR from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a trend for significant time main effect (p=0.067) and a trend for a condition*time interaction (p=0.085). No significant condition main effects were detected. Figure 87b shows the percent change from pre to post for each condition. A one-way ANOVA found a trend in percent change between conditions (p=0.071). Percent changes for HI, HI+AE, and BFR were 2.39 %, -5.21 %, and -3.87 %, respectively.

Figure 87a. Systemic Vascular Resistance **Figure 87b.** Change in SVR (%)



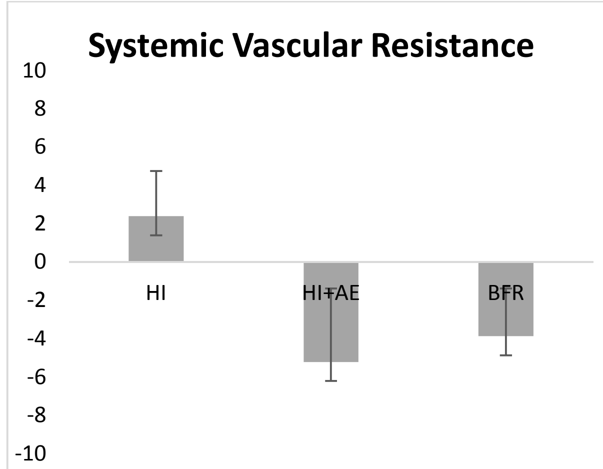


Figure 88 shows the change in TVI from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 88. Total Vascular Impedance

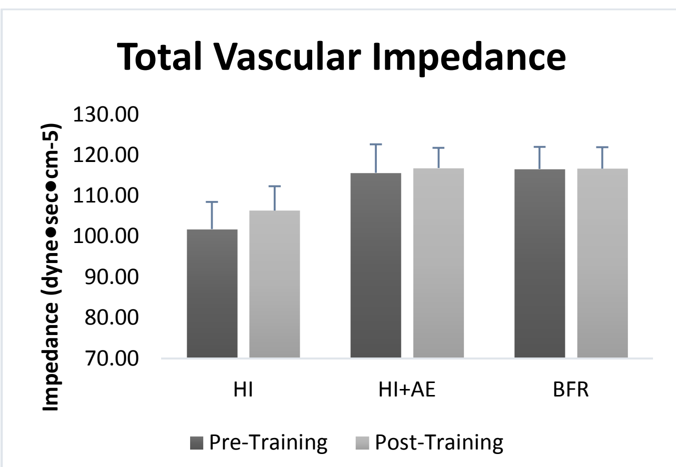
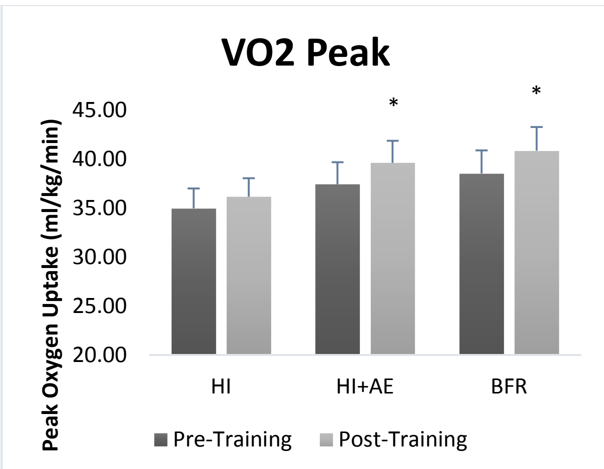


Figure 89a shows the change in peak oxygen uptake (VO2peak) from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected a significant time main effect ($p=0.001$), with no significant condition main effect or condition*time interactions. The follow up test showed that HI+AE (p=0.004) and BFR (p=0.023) significantly increased from baseline. Figure 89b shows the percent change from pre to post for each condition. Percent changes for HI, HI+AE, and BFR were 4.26 %, 6.21 %, and 6.33 %, respectively. No significant difference in % change was noted between conditions ($p > 0.05$).

Figure 89a. VO2 Peak



* Significantly different ($p < 0.05$) from baseline.
Values reported as mean ± SE.

Figure 89b. Change in VO2 Peak (%)

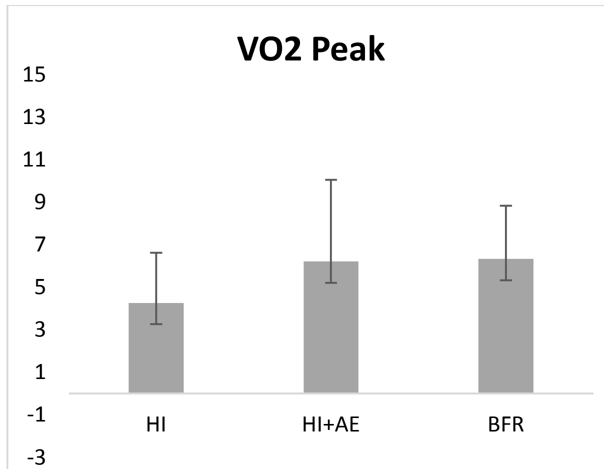
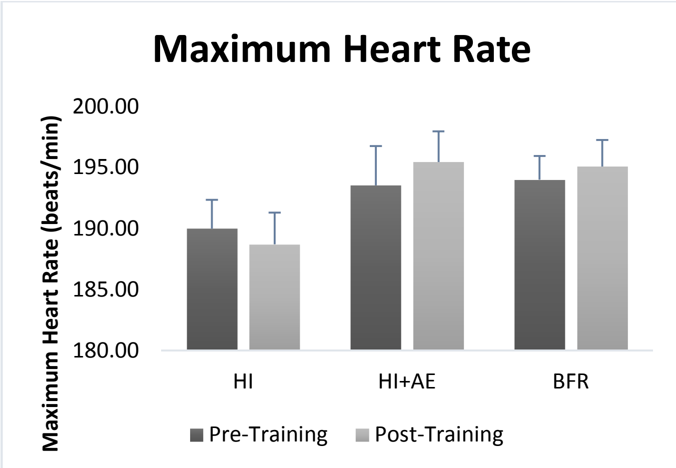


Figure 90 shows the change in maximum HR from pre- to post-training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. A two-way ANOVA with repeated measures detected no significant time main effect, condition main effect or condition*time interactions.

Figure 90. Maximum Heart Rate



CHAPTER V

DISCUSSION

This study was conducted to compare the effects of various resistance training protocols [1) low-load weight training with BFR in combination with low-intensity aerobic training. 2) Traditional high intensity weight training. 3) Traditional high intensity weight training in combination with moderate-intensity aerobic training] on adaptations in body composition, muscular strength, arterial stiffness, and hemodynamics in young males.

Body Composition

Resistance training has been consistently associated with improvements in body composition. (Esgin et al., 2017, Binder et al., 2005). Increases in lean mass or decreases in fat mass increase the ratio of muscle to fat tissue, improving body composition. The present study used the iDXA to assess changes in body composition before and after 8 weeks of resistance training. This method of measuring body composition has been considered the gold standard for several reasons, including accuracy, ease of use, precision, and segmental analysis (Shepherd et al., 2017). Changes in lean mass, fat mass, and fat distribution in this study will be discussed in further detail to understand the effects of each training protocol on these variables.

Major increases in arms and legs lean mass were seen in the HI and BFR groups following the training regimen, which is in agreement with previous studies (Farup et al, 2015, Vechin et al., 2018, Yasuda et al., 2011, Ozaki et al., 2013). A study performed by Farup et al. (2015) compared the effects of traditional resistance training to low-intensity BFR on arms hypertrophy. Results showed that both training groups significantly increased arms muscle volume after 6 weeks of training, which agrees with the results for the present study. Similarly, Vechin et al. (2018) compared HI-RT with BFR training on leg muscle strength and hypertrophy. Both training groups resulted in similar increases in leg muscle mass, even when the BFR group trained at a lower intensity. The increases in muscle mass following HI-RT are due to increased mechanical tension produced by generated force and stretch on the working muscle, leading to positive adaptations (Schoenfeld, 2010). The exact mechanisms in which BFR training produces these adaptations is not fully understood, but the most common explanation is that these positive adaptations are due to exercise-induced metabolic stress (Suga et al., 2010, Takada et al., 2012). Metabolic responses to BFR training have been shown to be similar to responses caused by traditional HI-RT (Suga et al., 2009, Karabulut, et al., 2014). With the accumulation of metabolic by-products, the activation of type III and IV afferent nerve fibers inhibit slow-twitch fiber motor units, forcing early fast-twitch fiber recruitment (Freitas et al., 2021). Since fast-twitch fibers are more responsive to hypertrophic adaptations, BFR training is able to elicit similar hypertrophic effects when compared to traditional resistance training.

Contrary to the findings for the HI and BFR groups, the HI+AE group did not result in significant lean mass increases from pre- to post-training. A reasonable explanation for the lack of significant increase in muscle mass for the HI+AE group could be the interference phenomenon (Docherty et al., 2000). This phenomenon refers to how combining endurance and strength training can affect muscle mass increases. A very recent meta-analysis and systematic review was performed to understand the effects of concurrent training on muscle hypertrophy (Lundberg et al., 2022). It was found that concurrent training may have a negative effect on muscle hypertrophy. This negative effect could be due acute increases in AMP-activated protein kinase (AMPK), which has been shown to inhibit mammalian target of rapamycin (mTOR) pathway signaling (Kishton et al., 2016). Studies have shown that AMPK activation is intensity-dependent, in which AMPK is activated at intensities at around 60% of maximal aerobic capacity (Richter et al., 2009). In addition, a study examining the effects of concurrent training and HI-RT only on satellite cell activity found that activity was impaired post-training following concurrent training (Babcock et al., 2012). In the HI-RT only group, satellite cell activity increased by 38% four days after training while the concurrent group had a 6% decrease. The negative effects on these mechanisms responsible for inducing muscle hypertrophy could be causing the attenuation of muscle growth.

Although the BFR group also performed aerobic exercise for 15 min following resistance training, increases in regional lean mass were seen from pre- to post-training. Studies have shown that BFR can induce muscle growth even when walking (Abe et al., 2006; Abe et al., 2010; Ozaki et al., 2011). A study performed on young population resulted in muscle cross-sectional area increases after 3 weeks of walking with BFR. It was found that growth hormone (GH) concentrations significantly increased after the walk with BFR, which could have led to the activation of mTOR, leading to muscle growth (Abe et al., 2006). In addition, a study by Kraemer et al. (1990) reported that HI-RT (about 80% 1-RM) produced a 100-fold increase in plasma concentration of GH. However, Takarada et al. (2000) observed a 290-fold increase in GH concentrations following low-intensity BFR training. It can be speculated that since GH activates the mTOR pathway, the greater increases in GH following BFR training could be one of the factors that have overcome the interference effect of aerobic exercise after resistance training.

Significant decreases in total fat mass from pre-training to post-training were not seen in the present study. The HI, HI+AE, and BFR groups had an average total fat mass percent change of -1.57 %, -1.93 %, and 0.68 %, respectively. On average, there was a 1.4% reduction in total fat mass following the training regimen, which agrees with a meta-analysis that focused on investigating the effects of resistance training on body fat in healthy adults (Wewege et al., 2021). It was reported that resistance training elicits an average reduction of 1.4% body fat percentage compared to non-exercise control. In this study, eight weeks of training was not enough time to elicit significant total fat mass decreases, therefore, it could be speculated that a longer study duration is needed to significantly change total fat mass without a dietary intervention.

Although total fat mass was not significantly different from pre- to post-training, region percent fat for the legs did change significantly in the HI and HI+AE groups. In addition, a trend for reduction of arms percent fat was seen in both high-intensity groups as well. It could be speculated that resistance training at higher intensities increases fat oxidation to a greater degree than low-intensity BFR. This claim is supported by a study performed by Ormsbee et al., (2007) which investigated how fat metabolism is affected during and posterior to a HI-RT session in young males. Subjects visited the laboratory in three separate occasions in which they performed a 1RM test on the first day. The second and third days were composed of either a HI-RT session or a non-exercise session. Results showed that glycerol levels were raised 78% during the HI-RT session and 75% after the session when compared to the control at the same time of day. Indirect calorimetry data saw a 105% higher fat oxidation after HI-RT when compared to control. The increase in lipolysis posterior to HI-RT could be due to increased levels of epinephrine and norepinephrine along with increases in growth hormone concentrations (Ormsbee et al., 2007, Bennard et al., 2005). These results suggest that intensity could be an important factor for regional reductions in fat mass.

Contrastingly, trunk region fat percentage did not have significant changes in any groups, as it showed almost no changes. This could be due to how body fat is distributed in males, where males tend to store more fat around the upper body, such as the abdomen and trunk areas (Santosa et al., 2008). This justification is supported by the lack of change in android fat mass from pre- to post-training. In addition, results in the present study demonstrated that arms, legs, and gynoid region fat percentage showed greater decreases when compared to trunk percent fat. This could be due to the aforementioned fact that males tend to store more android than gynoid fat. For most males, the body will oxidize fat from the legs and arms before it starts with fat stores around the trunk, which leads to decreases in arms and legs fat percentage.

Cardiovascular Responses

In the present study, several cardiovascular variables were measured using two different measuring tools. PWV and pulse wave analysis measurements were conducted noninvasively using SphygmoCor® XCEL (AtCor Medical Pty. Ltd., Sydney Australia). SphygmoCor devices are the only non-invasive devices cleared by the Food and Drug Administration that assess central aortic pressure waveform (Butlin et al., 2017). Elasticity of the large and small arteries was assessed by a non-invasive method using the radial artery tonometer (HDI/PulseWave CR-2000). Cohn et al. (1995) validated this technique for calculating capacitive (large artery) and oscillatory (small artery) arterial compliance with the use of pulse wave analysis and a modified Windkessel model of the circulation. One of the main objectives in the present study was to determine whether any of the cardiovascular variables that were measured showed a significant change from pre- to post-training following the training protocols.

As discussed previously, HI-RT has been associated with an increase in arterial stiffness (Miyachi et al., 2004, Cortez-Cooper et al., 2005, Ozaki et al., 2013, Kawano et al., 2006, Tagawa et al., 2018). There have been inconsistencies in the literature regarding this topic, since other studies have found no significant increases in arterial stiffness following a resistance training program (Rakobowchuk et al., 2005, Fahs et al., 2011. One of the methods to detect changes in arterial stiffness in the present study was PWV, which is widely considered as the gold standard for arterial stiffness measurements (Janner et al., 2010). PWV decreased approximately 9.6% in the HI+AE group, which was significantly different from BFR (-0.35%) and HI (1.34%). The lack of significant change in the HI group could be due to the exercise volume throughout the study. Casey et al., (2013) found that arterial stiffness was not altered with 12 weeks of resistance training due to total set volume per week, which is in agreement with a study performed by Rakobowchuk et al. (2005). Several studies that found significant increases in arterial stiffness reported very high set volumes per week (> 90 sets/wk) (Miyachi et al., 2004, Cortez-Cooper et al., 2005, Kawano et al., 2006). The present study implemented a total set volume of 36 sets/wk, which could be too low to cause negative responses in pulse wave velocity.

In contrast to HI-RT, aerobic endurance training has been associated with decreases in arterial stiffness, which have associated with decreases in oxidative stress (McClean et al., 2007). Current exercise guidelines recommend that most adults engage in moderate-intensity (e.g., 40%-<60% heart rate reserve) aerobic exercise for ≥30 min/day on ≥5 days/week (Ferguson, 2014). The significant percent change in PWV following the HI+AE group can be attributed to the effects of aerobic exercise after resistance training, which is in agreement with several studies on this topic (Kawano et al., 2006, Figueroa et al., 2011., Okamoto et al., 2007). Studies have found that these decreases in arterial stiffness could be due to improvements in blood pressure and increases in basal nitric oxide production (Otsuki et al., 2019, Montero et al., 2015). In the present study, significant improvements in both SBP and DBP were seen in the HI+AE group, therefore decreases in PWV could be partly attributed to blood pressure decreases.

Attenuating arterial stiffness is crucial to minimize risks of future cardiovascular disease, as it is in an independent risk factor for hypertension and cardiovascular mortality (Safar, 2018, Franklin et al., 1999, Dolan et al., 2006). The present study saw a significant condition main effect between HI and BFR in LAE. It should be noted that no negative effects on LAE were seen in the present study following the BFR protocol. These results are in agreement with previously mentioned studies that investigated the effect of BFR training on arterial elasticity, in which no negative effects were reported (Ozaki et al., 2013, Yasuda et al., 2013). The effects of HI-RT on arterial elasticity are a complicated topic, since there have been mixed results in several studies (Miyachi et al., 2004, Cortez-Cooper et al., 2005, Ozaki et al., 2013, Kawano et al., 2006, Tagawa et al., 2018, Rakobowchuk et al., 2005, Fahs et al., 2011). The present study did result in significant decreases in LAE following the HI protocol. Ozaki et al. (2013) suggested that increases in arterial stiffness following HI-RT could be due to acute elevations in SBP when performing the exercise, which may modify the arterial structure. These results suggest there could be a threshold in SBP where sustained elevations may cause arterial stiffness. BFR training may not reach that threshold, which could be the reason for the conservation of arterial compliance with this type of training. Conversely, HI+AE did not result in significant decreases in neither LAE or SAE, which agrees with a systemic review focusing on concurrent training effects on arterial stiffness (Li et al., 2015). The review concluded that concurrent training had little to no positive effects on arterial stiffness. In the present study, both LAE and SAE increased from pre- to post-training, but the increases did not reach significance. The lack of changes in LAE could be due to the how cardiac output responded to the training. It could be plausible that aerobic training intensity was not enough to increase cardiac output to a level that increases in LAE could be noted (Karabulut et al., 2019). Regarding SAE, Karabulut et al. (2019) performed an acute study to compare how arterial elasticity and hemodynamics would respond to 30, 45 or 60 min at 65% VO2max. It was seen that SAE increased significantly only in the 60 min condition, suggesting that longer exercise durations could be optimal to increase SAE. A longer exercise duration would lead to further reductions in oxidative stress and SVR (Roque et al., 2013). In addition, this would increase nitric oxide production, altering smooth muscle tone and further improving arterial elasticity (Wilkinson et al., 2002).

Another more indirect measure of arterial stiffness is known as augmentation index. Since augmentation index fluctuates with changes in HR, HR-corrected augmentation index (AIx@75) is used more frequently because it controls for HR variability (Wilkinson et al., 2000). In the present study, a trend was seen in HR-corrected augmentation index (AIx@75). Prior to starting the training, the mean Aix@75 was 0.73% in the HI+AE group. At the end of the training, the mean decreased to -7.14%, which can be interpreted as an indirect decrease in arterial stiffness. According to Janner et al. (2010), “AIx is dependent on arterial stiffness and the reflective properties of the arteries, that is the amplitude of the reflected wave and the reflectance point." AIx@75 has been speculated to change due to decreased sympathetic tone and enhanced endothelial function (DeSouza et al., 2000, Clarkson et al., 1999). With improvements in Aix@75 in the present study, it can be suggested that with only 15 min of aerobic exercise at 60% of VO2peak following HI-RT, increases in arterial stiffness can be attenuated. Since a trend was found in AIx@75 reductions, a longer study duration may be necessary to result in significant changes. Therefore, future research should focus on investigating if a longer study duration (>8 weeks) can lead to significant improvements in arterial stiffness.

Previous exercise guidelines mostly recommended aerobic exercise to improve cardiovascular health (Cornelissen et al., 2011). More recently, there have been several meta-analyses suggesting that blood pressure is not negatively affected by HI-RT (Kelley et al., 2000, Cornelissen et al., 2005). The results of the present study did not agree with the literature mentioned previously, since there was a small increase in SBP in the HI group. Beevers et al. (2001), stated that maintenance of blood pressure is dependent upon changes in CO and SVR. In addition, the study mentioned that SVR is determined by smaller arteries. In the present study, the HI group resulted in a very slight decrease in SAE (Avg Pre = 10.31 ml/mmHg*100, Avg Post =10.18 ml/mmHg*100), no change in CO, and a slight increase in SVR (2.39%). These cardiovascular changes can explain the slight increase in SBP that was seen in the HI group. Conversely, the HI+AE (-4.21%) resulted in significant reductions in SBP when compared to HI (3.36%) and BFR (-0.78%). A significant time main effect was seen in DBP, with significantly further decreases also noted in the HI+AE group (-9.15%) when compared to HI (0.21%) and BFR (-3.20%). These results suggest that a combination of HI-RT and aerobic exercise can lead to decreases in both DBP and SBP, which is in agreement with previous research on this topic (Sousa et al., 2013, Stewart et al., 2005, Schroeder et al., 2019). These decreases in blood pressure could be due to a decreased oxidative stress and SVR with moderate-intensity endurance training (Fagard et al., 2007).

The present study saw a trend ($p = 0.051$) in SVR decreases following the HI+AE protocol. There was a 5.21% decrease in SVR following the HI+AE protocol. A research study investigated the effects of concurrent training on muscle power and cardiovascular function in the elderly (Ferrari et al., 2016). The results indicated that there was a significant increase in vascular resistance following both concurrent training protocols. The difference in the results when compared to this study could be due to the intensity of aerobic exercise. During that study, the subjects exercised at 85-95% of HRmax, which could be too high to elicit positive vascular resistance adaptations. Fagard et al. (2007) suggested that increases in SVR can be seen with moderate-intensity endurance training, which is the intensity used in the HI+AE group for present study.

Decreases in SVR could also explain the significant decrease in MAP in the HI+AE group (-4.62%). Changes in MAP can be attributed to changes in CO and SVR (DeMers et al., 2022). Since SVR decreased and no changes were detected in CO following the HI+AE protocol, MAP decreased as a result of a reduction in vascular resistance. These decreases in MAP are in agreement with a study that investigated the effects of concurrent training on MAP in young individuals (Muthuraj, 2017). It was found that MAP significantly decreased after 12 weeks of training, which support the results for the present study. With these cardiovascular responses, it appears that concurrent training can be a safe option for people that seek to improve cardiovascular function.

A high resting HR has been associated with increased risk of cardiovascular disease, which could be due to an elevated blood pressure or increased sympathetic activity (Koskela et al., 2013). The present study found significant percent change in resting HR (-7.26%) in the HI+AE group. This result was supported by a significant increase in HR period following the HI+AE protocol as well. HR period refers to the length of an average derived central pulse, therefore an increase in HR period would correlate with a decrease in HR due to the time taken for each heartbeat (AtCor Medical, 2020, p. 33). These results are in agreement with previous research examining how concurrent training affects cardiovascular measures. The authors found a trend toward a reduction in resting HR with concurrent training. These reductions could be due to an increased parasympathetic tone along with increases in SV (Concu, 2009).

Along with decreases in resting HR, there was a significant increase in SV for the HI+AE group. A significant time main effect was seen for SV, but the HI+AE group resulted in significantly greater increases from baseline (HI = 2.22%, HI+AE = 11.22%, BFR = 1.53%). Research investigating the effects of concurrent training on SV is very limited, but one study found no change in SV following 12 weeks of concurrent training for 3 days/week (Ferketich et al., 1998). The inconsistency in these results could be due to subject population, since the study used elderly women. This can suggest that the younger population can elicit greater cardiovascular response to chronic concurrent training than the elderly. Since venous return is increased with training, a greater stretch of the heart's left ventricle causes a stronger contraction, increasing SV (Concu, 2009). It can be speculated that these cardiovascular adaptations are due to the 15 min of aerobic exercise after each session. The BFR group also performed 15 min of walking at the end, but the exercise was performed at 40% of VO2peak. Since the HI+AE group exercised at 60% of VO2peak, intensity could be the key factor in eliciting greater cardiovascular adaptations.

One interesting finding in the present study was the significant time main effect that was found in PP. Measured by the HDI/Pulsewave CR-2000, PP increased in all groups (HI = 7.22%, HI+AE = 2.08%, BFR = 2.56%), but increased significantly only in the HI group. These results do not replicate the findings in a previous study that measured the effects of a 12-week resistance training program on arterial compliance and other hemodynamics in young adults. It was found that PP significantly decreased following the HI-RT training regimen. The inconsistencies in the results could be due to changes in SV and arterial compliance with training. According to Dart et al. (2001), arterial compliance can be estimated by using the following equation: C = SV/PP. Examining this equation, it can be concluded that increases in PP can be associated with increases in SV or decreases in compliance. Since the present study did find a significant reduction in arterial compliance in the HI group, it can be speculated that a reduced peripheral arterial compliance was mostly responsible for the significant rise in PP for the HI group. HI+AE had a significantly greater increase in SV when compared to HI and BFR, but greater increases in arterial compliance following the HI+AE protocol can explain the attenuation of further increases in PP.

Cardiorespiratory Fitness

Peak oxygen uptake has been shown to be an acceptable estimate of cardiorespiratory fitness (CRF) (Green et al., 2018). In this study, CRF was measured as VO2peak using the Bruce Protocol, which is a very popular maximal test that has been found to have the least amount of error when compared to other tests (Grant et al., 1999). Results showed VO2peak increased significantly from pre- to post-training in the HI+AE and BFR group. The increase in the HI group (4.26%) agree with previous research on the effects of HI-RT on VO2max in untrained individuals. Increases from 5% to 8% have been seen in untrained individuals, which is very close to the increases that were seen in this study (Fleck, 1988). This study found that 15 min of aerobic exercise at either 40% with BFR or 60 % of VO2peak was enough to significantly increase VO2peak from baseline. Research studies have consistently shown that concurrent training can produce significant improvements in VO2max (Ferketich et al., 1998, Davis et al., 2008, Mohamadzadeh et al., 2017). These increases in CRF could be associated with increases in SV and a higher cardiac efficiency (Lundby et al., 2016). Since all of the previously mentioned studies had training protocols of 3 days/week, this study could serve as a reference point for future studies seeking to investigate a minimum training volume to increase VO2peak.

Strength Measures

The present study compared how low-intensity BFR (20-40% of 1RM) training and HI-RT (70-80% of 1RM) could affect strength measures. The American College of Sports Medicine recommends lifting at an intensity of at least 60-70% of 1RM in order to induce strength and hypertrophic adaptations (ACSM, 2009). BFR training has been associated with increases in strength following a training regimen, exercising at intensities of 20% of 1RM (Yasuda et al., 2011b). Due to the low load on the joints, BFR training can be a key factor when it comes to improving strength in special populations. For this reason, this study sought to determine whether BFR and HI-RT could elicit similar strength adaptations, even if exercising at completely different intensities.

In the present study, significant increases in 1RM strength were seen in all three groups. All exercises that were performed (leg press, leg extension, leg curl, incline bench press, lat pulldown, and shoulder press) resulted in significant increases from pre- to post-training. No significant differences were seen between groups in 1RM increase for any exercise. The results for the present study are in agreement with several studies that investigated how strength is affected with concurrent training (Balabinis et al., 2003, Sillanpaa et al., 2008, Sillanpaa et al., 2009). Earlier studies had demonstrated a lower response in strength with concurrent training when compared to HI-RT only (Dolezal et al., 1998, Hakkinen et al., 2003, Hickson, 1980). It has been speculated that the decreases are likely caused by overreaching (Wilson et al., 2012). The addition of aerobic exercise to HI-RT could result in too much stress on the body whenever volume is high, resulting in lower strength adaptations. The inconsistencies in the results could therefore be due to how aerobic exercise is structured. Changes in exercise frequency, duration, and/or modality could explain the high discrepancies in the results.

Similar to research on concurrent training and strength, the effects of BFR training on dynamic strength are inconsistent. The results in the present study are in agreement with various research studies that compared low-intensity BFR with HI-RT on strength adaptations (Ozaki et al., 2013, Karabulut et al., 2010., Yasuda et al., 2011b). The increases in strength seen in these studies are speculated to be due to neural and hypertrophic adaptations with BFR training. Conversely, there have also been several studies that reported a significant difference between low-intensity BFR and HI-RT on strength adaptations (Yasuda et al., 2011a, Vechin et al., 2018). These studies reported that HI-RT resulted in significant increases in strength compared to BFR training. The inconsistencies in the results have been theorized to be due to study population, training frequency, training duration, and/or cuff pressures (Loenneke et al., 2012).

Isometric and isokinetic strength were also measured to understand how strength changes across the different muscle actions. The isometric test, known as a maximum voluntary contraction (MVC), had significant increases from pre- to post-training in all groups. These results are in agreement with several previous studies examining the effects of BFR on MVC. (Loenneke et al., 2015, Takarada et al., 2002, Scott et al., 2016). These studies found that BFR training significantly increased MVC when compared to baseline values. In addition, results for the HI and HI+AE groups agree with previous studies focusing on MVC responses to HI-RT (Andersen et al., 2010, Andersen et al., 2006). These results indicate that both HI-RT and low-intensity BFR training can elicit similar adaptations in isometric strength even when no isometric training was performed.

Isokinetic strength also increased significantly in all three groups. The 60°/s and 180°/s isokinetic test consisted of 10 repetitions of leg extension (away) followed by leg curl (toward). Neither the away nor the toward portion of the 60°/s test resulted in significant increases in any group. The groups had average increases of 6.18% (HI), 3.98% (HI+AE), 1.54% (BFR) in torque for this test, but the variation in the results could be the cause for the lack of significance. When it comes to the 180°/s isokinetic test, both the away and toward portions significantly improved from pre- to post-training in all groups. The results of the present study partially agree with previous research on this topic. Several studies have found that resistance training increases both the 60°/s and 180°/s isokinetic test values (Oliveira et al., 2015, Ferrari et al., 2016, Kang et al., 2015). One of the studies mentioned that isokinetic strength testing has become a gold standard and is known for the validity it shows in clinical and research setting (Oliveira et al., 2015). In the present study, the lack of significant increase for the 60°/s test could be due to the speed of training. Since training repetition speeds resembled the 180°/s test, it could be possible that significant strength adaptations were specific to that speed only. Nevertheless, these results indicate that HI-RT and BFR training can elicit similar increases in isotonic, isometric, and isokinetic strength after 8 weeks of training.

Conclusions

This study was conducted to compare the effects of various resistance training protocols [1) low-load weight training with BFR in combination with low-intensity aerobic training. 2) Traditional high intensity weight training. 3) Traditional high intensity weight training in combination with moderate-intensity aerobic training] on adaptations in body composition, muscular strength, arterial stiffness, and hemodynamics in young males.

The research questions asked were:

1. Did the HI+AE and BFR groups result in significant differences in arterial elasticity and hemodynamics compared to HI?
2. Did BFR result in similar muscular and strength adaptations as both high-intensity groups?
3. Did the HI+AE and BFR groups result in significantly greater VO2peak compared to HI?
4. Did the HI+AE and BFR groups result in similar increases in lean mass with further decreases in fat mass compared to HI?

Research Hypothesis 1. HI+AE and BFR groups will result in significant improvements in arterial elasticity and hemodynamic responses than HI.

The results of the present study partially supported this hypothesis. Significant decreases in arterial elasticity were seen in the HI group even with low set volume per week. This decrease in LAE could be due to elevation in SBP in the HI group. Although LAE and SAE did improve in the HI+AE group, significance was not reached. Hemodynamic responses were significantly improved in the HI+AE group. Improvements in SBP, DBP, MAP, HR, SV and a trend for SVR were seen from pre- to post-testing in the HI+AE group. The HI group resulted in significant increases in PP.

Research Hypothesis 2. BFR will result in similar muscular and strength adaptations compared to both high-intensity groups.

The results of the present study partially supported this hypothesis. Major increases in arms, legs, and gynoid lean mass were seen in the HI and BFR groups. The lack of significance in lean mass increases for the HI+AE could be due to the intensity of aerobic exercise after resistance training, which has been suggested to interfere with muscle growth. No significant difference between groups was found in any strength variable, which supports past results reporting similar increases in strength with BFR training compared to HI-RT. Even with a significantly lower intensity and load on the joints, BFR training resulted in positive adaptations on the musculoskeletal system.

Research Hypothesis 3. HI+AE and BFR will result in significant increases in VO2peak when compared to HI.

The results of the present study did support this hypothesis. VO2peak was significantly greater from pre- to post-training in both the HI+AE and BFR groups. There was no significant difference in the HI group when compared to baseline. With these results, it can be concluded that two 15-min of aerobic exercise per week, either at 40% of VO2peak with BFR or 60% of VO2peak, can elicit greater effects on VO2peak when compared to HI-RT only.

Research Hypothesis 4. HI+AE and BFR will result in similar increases in lean mass as HI with further decreases in fat mass.

The results of the present study did not support this hypothesis. As mentioned previously, major increases in arms, legs and gynoid lean mass were seen in the HI and BFR groups. In addition, similar decreases in legs and arms region % fat were seen in the HI and HI+AE groups. It can be concluded that BFR resulted in similar lean mass response in several body composition variables as the HI group even at much lower intensities. However, the HI group resulted in significant decreases in arms and legs region percent fat as well.

This study is the first to compare the effects of an 8-week resistance training program with three different protocols (BFR, HI, HI+AE) on body composition, muscular strength, hemodynamic variables, and arterial elasticity in young, healthy males. The present study resulted in similar increases in regional lean mass and strength while maintaining arterial compliance in the BFR group. These results can be important for populations who cannot perform HI-RT, having an alternative method that has similar effects on regional lean mass and muscle strength even at lower intensities. Populations such as the elderly or even injured athletes are among the many populations that could benefit from the low loads used with BFR training.

In conclusion, individuals whose main goal is to improve body composition should focus on performing HI-RT. The present study reported significant increases in lean mass and decreases in regional fat mass following this protocol, making it the most optimal to improve body composition. However, if the goal is to mainly improve muscle strength and hemodynamics, HI+AE would be the best option. The present study saw a significant improvement in hemodynamics following the HI+AE protocol, with similar strength improvements as the other two groups. Lastly, individuals who simply are unable to perform exercise at high intensities have an alternative option to increase regional lean mass, muscle strength, and CRF without negatively affecting cardiovascular responses. BFR was the only protocol that resulted in increases in lean mass without negatively affecting cardiovascular responses. This study showed that BFR training can induce similar regional lean mass and muscle strength increases as HI-RT even at a lower intensity and total volume. Since this study was performed on a young and healthy population, the responses to exercise training protocols used in the present study may be different for females and different age groups. Therefore, readers should take factors such as age, gender, and disease into consideration before implementing this type of training.

The present study can serve as a basis for future studies wanting to investigate the effects of HI-RT combined with aerobic exercise. Further increases in arterial elasticity were seen in the HI+AE group when compared to the BFR group even when both groups performed 15 min of aerobic exercise after resistance training. Since aerobic intensity was lower in the BFR group (40% of VO2peak), it can be speculated that a moderate-intensity is needed to elicit positive arterial adaptations. Additionally, the HI+AE group resulted in superior cardiovascular responses, supported by decreases in resting SBP, DBP, MAP, SVR, HR and an increase in SV. It can be concluded that 15 min of aerobic exercise after resistance training is enough to produce significant improvements in the cardiovascular system. However, these cardiovascular adaptations could have caused an interference with lean mass increases. Further research should be done to investigate if a longer study duration can result in significant improvements in arterial elasticity.

REFERENCES

Abe, T., Kearns, C. F., & Sato, Y. (2006). Muscle size and strength are increased following walk training with restricted venous blood flow from the leg muscle, Kaatsu-walk t raining. Journal of applied physiology, 100(5), 1460-1466.

Abe, T., Sakamaki, M., Fujita, S., Ozaki, H., Sugaya, M., Sato, Y., & Nakajima, T. (2010). Effects of low-intensity walk training with restricted leg blood flow on muscle strength and aerobic capacity in older adults. Journal of geriatric physical therapy, 33(1), 34-40.

Abe, T., Fujita, S., Nakajima, T., Sakamaki, M., Ozaki, H., Ogasawara, R., ... & Ishii, N. (2010). Effects of low-intensity cycle training with restricted leg blood flow on thigh muscle volume and VO2max in young men. *Journal of sports science & medicine*, *9*(3), 452.

Agarwal, S. K. (2012). Cardiovascular benefits of exercise. *International journal of general medicine*, *5*, 541.

Amano, S., Ludin, A. F. M., Clift, R., Nakazawa, M., Law, T. D., Rush, L. J., ... & Clark, B. C. (2016). Effectiveness of blood flow restricted exercise compared with standard exercise in patients with recurrent low back pain: study protocol for a randomized controlled trial. *Trials*, *17*(1), 1-11.

American College of Sports Medicine. (2009). American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Medicine and science in sports and exercise*, *41*(3), 687-708.

Andersen, L. L., & Aagaard, P. (2006). Influence of maximal muscle strength and intrinsic muscle contractile properties on contractile rate of force development. *European journal of applied physiology*, *96*(1), 46-52.

Andersen, L. L., Andersen, J. L., Zebis, M. K., & Aagaard, P. (2010). Early and late rate of force development: differential adaptive responses to resistance training?. *Scandinavian journal of medicine & science in sports*, *20*(1), e162-e169.

AtCor Medical Pty. (2020). Sphygmocor XCEL: Operator's manual. Sydney, AUS.

Balabinis, C. P., Psarakis, C. H., Moukas, M., Vassiliou, M. P., & Behrakis, P. K. (2003). Early phase changes by concurrent endurance and strength training. *Journal of Strength and Conditioning Research*, *17*(2), 393-4

Beevers, G., Lip, G. Y., & O'Brien, E. (2001). The pathophysiology of hypertension. *Bmj*, *322* (7291), 912-916.

Bennard, P., Imbeault, P., & Doucet, É. (2005). Maximizing acute fat utilization: effects of exercise, food, and individual characteristics. *Canadian journal of applied physiology*, *30*(4), 475-499.

Binder, E. F., Yarasheski, K. E., Steger-May, K., Sinacore, D. R., Brown, M., Schechtman, K. B., & Holloszy, J. O. (2005). Effects of progressive resistance training on body composition in frail older adults: results of a randomized, controlled trial. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, *60*(11), 1425-1431.

Butlin M and Qasem A. Large Artery Stiffness Assessment Using SphygmoCor Technology. *Pulse (Basel)* 4: 180-192, 2017.

Casey, D. P., Beck, D. T., & Braith, R. W. (2007). Progressive resistance training without volume increases does not alter arterial stiffness and aortic wave reflection. *Experimental biology and medicine*, *232*(9), 1228-1235.

Cecelja, M., & Chowienczyk, P. (2012). Role of arterial stiffness in cardiovascular disease. *JRSM cardiovascular disease*, *1*(4), 1-10.

Clarkson, P., Montgomery, H. E., Mullen, M. J., Donald, A. E., Powe, A. J., Bull, T., ... & Deanfield, J. E. (1999). Exercise training enhances endothelial function in young men. *Journal of the American College of Cardiology*, *33*(5), 1379-1385.

Cohn, J. N., Finkelstein, S., McVeigh, G., Morgan, D., LeMay, L., Robinson, J., & Mock, J. (1995). Noninvasive pulse wave analysis for the early detection of vascular disease. *Hypertension*, *26*(3), 503-508.

Concu, A. (2009). Stroke volume: Acute and Chronic Effects of Exercise. *STROKE*.

Curty, V. M., Melo, A. B., Caldas, L. C., Guimarães‐Ferreira, L., de Sousa, N. F., Vassallo, P. F., ... & Barauna, V. G. (2018). Blood flow restriction attenuates eccentric exercise‐induced muscle damage without perceptual and cardiovascular overload. *Clinical physiology and functional imaging*, *38*(3), 468-476.

Cornelissen, V. A., & Fagard, R. H. (2005). Effect of resistance training on resting blood pressure: a meta-analysis of randomized controlled trials. *Journal of hypertension*, *23*(2), 251-259.

Cornelissen, V. A., Fagard, R. H., Coeckelberghs, E., & Vanhees, L. (2011). Impact of resistance training on blood pressure and other cardiovascular risk factors: a meta-analysis of randomized, controlled trials. *Hypertension*, *58*(5), 950-958.

Cortez-Cooper, M. Y., DeVan, A. E., Anton, M. M., Farrar, R. P., Beckwith, K. A., Todd, J. S., & Tanaka, H. (2005). Effects of high intensity resistance training on arterial stiffness and wave reflection in women. *American journal of hypertension*, *18*(7), 930-934.

Dankel, S. J., Buckner, S. L., Counts, B. R., Jessee, M. B., Mouser, J. G., Mattocks, K. T., ... & Loenneke, J. P. (2017). The acute muscular response to two distinct blood flow restriction protocols. *Physiology International*, *104*(1), 64-76.

Dart, A. M., & Kingwell, B. A. (2001). Pulse pressure—a review of mechanisms and clinical relevance. *Journal of the American College of Cardiology*, *37*(4), 975-984.

Davis, W. J., Wood, D. T., Andrews, R. G., Elkind, L. M., & Davis, W. B. (2008). Concurrent training enhances athletes' cardiovascular and cardiorespiratory measures. *The Journal of Strength & Conditioning Research*, *22*(5), 1503-1514.

DeMers, D., & Wachs, D. (2021). Physiology, mean arterial pressure. In *StatPearls [Internet]*. StatPearls Publishing.

DeSouza, C. A., Shapiro, L. F., Clevenger, C. M., Dinenno, F. A., Monahan, K. D., Tanaka, H., & Seals, D. R. (2000). Regular aerobic exercise prevents and restores age-related declines in endothelium-dependent vasodilation in healthy men. *Circulation*, *102*(12), 1351-1357.

Docherty, D., & Sporer, B. (2000). A proposed model for examining the interference phenomenon between concurrent aerobic and strength training. *Sports medicine*, *30*(6), 385-394.

Dolan, E., Thijs, L., Li, Y., Atkins, N., McCormack, P., McClory, S., ... & Stanton, A. V. (2006). Ambulatory arterial stiffness index as a predictor of cardiovascular mortality in the Dublin Outcome Study. *Hypertension*, *47*(3), 365-370.

Dolezal, B. A., & Potteiger, J. A. (1998). Concurrent resistance and endurance training influence basal metabolic rate in nondieting individuals. *Journal of applied physiology*, *85*(2), 695-700.

Esgin, T., Johnston, N., Rowley, K., de Villarreal, E. S., & Newton, R. (2017). Effect of 12 weeks combined aerobic and resistance training on fitness, arterial stiffness and body composition in Indigenous Australian men and women. *Journal of Science and Medicine in Sport*, *20*, 43.

Fagard, R. H., & Cornelissen, V. A. (2007). Effect of exercise on blood pressure control in hypertensive patients. *European Journal of Preventive Cardiology*, *14*(1), 12-17.

Fahs, C. A., Rossow, L. M., Loenneke, J. P., Thiebaud, R. S., Kim, D., Bemben, D. A., & Bemben, M. G. (2012). Effect of different types of lower body resistance training on arterial compliance and calf blood flow. *Clinical physiology and functional imaging*, *32*(1), 45-51.

Farup, J., De Paoli, F., Bjerg, K., Riis, S., Ringgard, S., & Vissing, K. (2015). Blood flow restricted and traditional resistance training performed to fatigue produce equal muscle hypertrophy. *Scandinavian journal of medicine & science in sports*, *25*(6), 754-763.

Ferguson, B. (2014). ACSM's guidelines for exercise testing and prescription 9th Ed. 2014. *The Journal of the Canadian Chiropractic Association*, *58*(3), 328.

Ferketich, A. K., Kirby, T. E., & Alway, S. E. (1998). Cardiovascular and muscular adaptations to combined endurance and strength training in elderly women. *Acta Physiologica Scandinavica*, *164*(3), 259-267.

Ferrari, R., Fuchs, S. C., Kruel, L. F. M., Cadore, E. L., Alberton, C. L., Pinto, R. S., ... & Umpierre, D. (2016). Effects of different concurrent resistance and aerobic training frequencies on muscle power and muscle quality in trained elderly men: a randomized clinical trial. *Aging and disease*, *7*(6), 697.

Figueroa, A., Park, S. Y., Seo, D. Y., Sanchez-Gonzalez, M. A., & Baek, Y. H. (2011). Combined resistance and endurance exercise training improves arterial stiffness, blood pressure, and muscle strength in postmenopausal women. *Menopause*, *18*(9), 980-984.

Fleck, S. J. (1988). Cardiovascular adaptations to resistance training. *Medicine and science in sports and exercise*, *20*(5 Suppl), S146-51.

Franklin, S. S., Khan, S. A., Wong, N. D., Larson, M. G., & Levy, D. (1999). Is pulse pressure useful in predicting risk for coronary heart disease? The Framingham Heart Study. *Circulation*, *100*(4), 354-360.

Freitas, E. D., Karabulut, M., & Bemben, M. G. (2021). The evolution of blood flow restricted exercise. *Frontiers in Physiology*, 2179.

Grant, J. A., Joseph, A. N., & Campagna, P. D. (1999). The prediction of VO2max: a comparison of 7 indirect tests of aerobic power. *The Journal of Strength & Conditioning Research*, *13*(4), 346-352.

Green, S., & Askew, C. (2018). VO2peak is an acceptable estimate of cardiorespiratory fitness but not VO2max. *Journal of Applied Physiology*.

Häkkinen, K., Alen, M., Kraemer, W. J., Gorostiaga, E., Izquierdo, M., Rusko, H., ... & Paavolainen, L. (2003). Neuromuscular adaptations during concurrent strength and endurance training versus strength training. *European journal of applied physiology*, *89*(1), 42-52.

Heffernan, K. S., Jae, S. Y., Edwards, D. G., Kelly, E. E., & Fernhall, B. (2007). Arterial stiffness following repeated Valsalva maneuvers and resistance exercise in young men. *Applied physiology, nutrition, and metabolism*, *32*(2), 257-264.

Hickson, R. C. (1980). Interference of strength development by simultaneously training for strength and endurance. *European journal of applied physiology and occupational physiology*, *45*(2), 255-263.

Hughes, L., Paton, B., Rosenblatt, B., Gissane, C., & Patterson, S. D. (2017). Blood flow restriction training in clinical musculoskeletal rehabilitation: a systematic review and meta-analysis. *British Journal of Sports Medicine*, *51*(13), 1003-1011.

Jablonski, K. L., Donato, A. J., Fleenor, B. S., Nowlan, M. J., Walker, A. E., Kaplon, R. E., ... & Seals, D. R. (2015). Reduced large elastic artery stiffness with regular aerobic exercise in middle-aged and older adults: potential role of suppressed nuclear factor κ B signalling. *Journal of hypertension*, *33*(12), 2477.

Janner, J. H., Godtfredsen, N. S., Ladelund, S., Vestbo, J., & Prescott, E. (2010). Aortic augmentation index: reference values in a large unselected population by means of the SphygmoCor device. *American journal of hypertension*, *23*(2), 180-185.

Kang, D. Y., Kim, H. S., Lee, K. S., & Kim, Y. M. (2015). The effects of bodyweight-based exercise with blood flow restriction on isokinetic knee muscular function and thigh circumference in college students. *Journal of physical therapy science*, *27*(9), 2709-2712.

Karabulut, M., Abe, T., Sato, Y., & Bemben, M. G. (2010). The effects of low-intensity resistance training with vascular restriction on leg muscle strength in older men. *European journal of applied physiology*, *108*(1), 147-155.

Karabulut, M., Bemben, D. A., Sherk, V. D., Anderson, M. A., Abe, T., & Bemben, M. G. (2011). Effects of high-intensity resistance training and low-intensity resistance training with vascular restriction on bone markers in older men. *European journal of applied physiology*, *111*(8), 1659-1667.

Karabulut, M., Mccarron, J., Abe, T., Sato, Y., & Bemben, M. (2011). The effects of different initial restrictive pressures used to reduce blood flow and thigh composition on tissue oxygenation of the quadriceps. *Journal of sports sciences*, *29*(9), 951-958.

Karabulut, M., Leal Jr, J. A., Garcia, S. D., Cavazos, C., & Bemben, M. (2014). Tissue oxygenation, strength and lactate response to different blood flow restrictive pressures. *Clinical physiology and functional imaging*, *34*(4), 263-269.

Karabulut, M., Lopez, J. A., & Karabulut, U. (2020). Aerobic training session length affects arterial elasticity. *Clinical physiology and functional imaging*, *40*(1), 14–20. https://doi.org/10.1111/cpf.12596

Karabulut, M., Parra, R., Bemben, M. G., & Karabulut, U. (2020). Arterial Elasticity Response To Short-term Endurance Resistance And Blood Flow Restriction Training In Older Men: 2082

Kawano, H., Tanaka, H., & Miyachi, M. (2006). Resistance training and arterial compliance: keeping the benefits while minimizing the stiffening. *Journal of hypertension*, *24*(9), 1753-1759.

Kelley, G. A., Kelley, K. A., & Vu Tran, Z. (2001). Aerobic exercise and resting blood pressure: a meta□analytic review of randomized, controlled trials. *Preventive cardiology*, *4*(2), 73-80.

Kishton, R. J., Barnes, C. E., Nichols, A. G., Cohen, S., Gerriets, V. A., Siska, P. J., ... & Rathmell, J. C. (2016). AMPK is essential to balance glycolysis and mitochondrial metabolism to control T-ALL cell stress and survival. *Cell metabolism*, *23*(4), 649-662.

Koskela, J. K., Tahvanainen, A., Haring, A., Tikkakoski, A. J., Ilveskoski, E., Viitala, J., ... & Pörsti, I. H. (2013). Association of resting heart rate with cardiovascular function: a cross-sectional study in 522 Finnish subjects. *BMC cardiovascular disorders*, *13*(1), 1-11.

Kraemer, W. J., Marchitelli, L., Gordon, S. E., Harman, E., Dziados, J. E., Mello, R., ... & Fleck, S. J. (1990). Hormonal and growth factor responses to heavy resistance exercise protocols. *Journal of Applied Physiology*, *69*(4), 1442-1450.

Miyachi, M., Kawano, H., Sugawara, J., Takahashi, K., Hayashi, K., Yamazaki, K., ... & Tanaka, H. (2004). Unfavorable effects of resistance training on central arterial compliance: a randomized intervention study. *Circulation*, *110*(18), 2858-2863.

Laurent, S., & Boutouyrie, P. (2007). Arterial stiffness: a new surrogate end point for cardiovascular disease?. *Journal of nephrology*, *20 Suppl 12*, S45–S50.
Li, Y., Hanssen, H., Cordes, M., Rossmeissl, A., Endes, S., & Schmidt-Trucksäss, A. (2015). Aerobic, resistance and combined exercise training on arterial stiffness in normotensive and hypertensive adults: A review. *European journal of sport science*, *15*(5), 443-457.

Lixandrão, M. E., Ugrinowitsch, C., Laurentino, G., Libardi, C. A., Aihara, A. Y., Cardoso, F. N., ... & Roschel, H. (2015). Effects of exercise intensity and occlusion pressure after 12 weeks of resistance training with blood-flow restriction. *European journal of applied physiology*, *115*(12), 2471-2480.

Loenneke, J. P., Wilson, J. M., Marín, P. J., Zourdos, M. C., & Bemben, M. G. (2012). Low intensity blood flow restriction training: a meta-analysis. *European journal of applied physiology*, *112*(5), 1849-1859.

Loenneke, J. P., Kim, D., Fahs, C. A., Thiebaud, R. S., Abe, T., Larson, R. D., ... & Bemben, M. G. (2015). Effects of exercise with and without different degrees of blood flow restriction on torque and muscle activation. *Muscle & nerve*, *51*(5), 713-721.

Lundberg, T. R., Feuerbacher, J. F., Sünkeler, M., & Schumann, M. (2022). The Effects of Concurrent Aerobic and Strength Training on Muscle Fiber Hypertrophy: A Systematic Review and Meta-Analysis. *Sports Medicine*, 1-13.

Lundby, C., Montero, D., & Joyner, M. (2017). Biology of VO2max: looking under the physiology lamp. *Acta Physiologica*, *220*(2), 218-228.

McClean, C. M., Mc Laughlin, J., Burke, G., Murphy, M. H., Trinick, T., Duly, E., & Davison, G. W. (2007). The effect of acute aerobic exercise on pulse wave velocity and oxidative stress following postprandial hypertriglyceridemia in healthy men. *European journal of applied physiology*, *100*(2), 225-234.

McDonald, D. A. (1974). Blood flow in arteries.

Miyachi, M., Kawano, H., Sugawara, J., Takahashi, K., Hayashi, K., Yamazaki, K., Tabata, I., & Tanaka, H. (2004). Unfavorable effects of resistance training on central arterial compliance: a randomized intervention study. *Circulation*, *110*(18), 2858–2863. https://doi.org/10.1161/01.CIR.0000146380.08401.99

Mohamadzadeh Salamat, K. (2017). The effect of two types of concurrent training on Vo2max, maximal strength and body fat percentage in young men. *Report of Health Care*, *3*(1), 17-22.

Montero, D., Vinet, A., & Roberts, C. K. (2015). Effect of combined aerobic and resistance training versus aerobic training on arterial stiffness. *International journal of cardiology*, *178*, 69-76.

Muthuraj, M. (2017). Impact of concurrent strength and endurance training on mean arterial pressure. *International Journal of Physical Education, Yoga and Health Sciences*, *4*(1), 16-17.

Neto, G. R., Santos, H. H., Sousa, J. B., Júnior, A. T., Araújo, J. P., Aniceto, R. R., & Sousa, M. S. (2014). Effects of high-intensity blood flow restriction exercise on muscle fatigue. *Journal of human kinetics*, *41*(1), 163-172.

Nystoriak, M. A., & Bhatnagar, A. (2018). Cardiovascular effects and benefits of exercise. *Frontiers in cardiovascular medicine*, 135.

Okamoto, T., Masuhara, M., & Ikuta, K. (2007). Combined aerobic and resistance training and vascular function: effect of aerobic exercise before and after resistance training. *Journal of applied physiology*, *103*(5), 1655-1661.

Oliveira, P. F. A., Gadelha, A. B., Gauche, R., Paiva, F. M. L., Bottaro, M., Vianna, L. C., & Lima, R. M. (2015). Resistance training improves isokinetic strength and metabolic syndrome-related phenotypes in postmenopausal women. *Clinical interventions in aging*, *10*, 1299.

Ormsbee, M. J., Thyfault, J. P., Johnson, E. A., Kraus, R. M., Choi, M. D., & Hickner, R. C. (2007). Fat metabolism and acute resistance exercise in trained men. *Journal of Applied Physiology*.

Otsuki, T., Namatame, H., Yoshikawa, T., & Zempo-Miyaki, A. (2020). Combined aerobic and low-intensity resistance exercise training increases basal nitric oxide production and decreases arterial stiffness in healthy older adults. *Journal of Clinical Biochemistry and Nutrition*, *66*(1), 62-66.

Ozaki, H., Miyachi, M., Nakajima, T., & Abe, T. (2011). Effects of 10 weeks walk training with leg blood flow reduction on carotid arterial compliance and muscle size in the elderly adults. *Angiology*, *62*(1), 81-86.

Ozaki, H., Yasuda, T., Ogasawara, R., Sakamaki-Sunaga, M., Naito, H., & Abe, T. (2013). Effects of high-intensity and blood flow-restricted low-intensity resistance training on carotid arterial compliance: role of blood pressure during training sessions. *European journal of applied physiology*, *113*(1), 167-174.

Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: a review of mental and physical health benefits associated with physical activity. *Current opinion in psychiatry*, *18*(2), 189-193.

Rakobowchuk, M., McGowan, C. L., De Groot, P. C., Bruinsma, D., Hartman, J. W., Phillips, S. M., & MacDonald, M. J. (2005). Effect of whole body resistance training on arterial compliance in young men. *Experimental physiology*, *90*(4), 645-651.

Renzi, C. P., Tanaka, H., & Sugawara, J. U. N. (2010). Effects of leg blood flow restriction during walking on cardiovascular function. *Medicine and science in sports and exercise*, *42*(4), 726.

Richter, E. A., & Ruderman, N. B. (2009). AMPK and the biochemistry of exercise: implications for human health and disease. *Biochemical Journal*, *418*(2), 261-275.

Riley, W. A., Freedman, D. S., Higgs, N. A., Barnes, R. W., Zinkgraf, S. A., & Berenson, G. S. (1986). Decreased arterial elasticity associated with cardiovascular disease risk factors in the young. Bogalusa Heart Study. *Arteriosclerosis: An Official Journal of the American Heart Association, Inc.*, *6*(4), 378-386.

Roque, F. R., Briones, A. M., García□Redondo, A. B., Galán, M., Martínez□Revelles, S., Avendaño, M. S., ... & Salaices, M. (2013). Aerobic exercise reduces oxidative stress and improves vascular changes of small mesenteric and coronary arteries in hypertension. *British journal of pharmacology*, *168*(3), 686-703.

Safar, M. E. (2018). Arterial stiffness as a risk factor for clinical hypertension. *Nature Reviews Cardiology*, *15*(2), 97-105.

Santosa, S., & Jensen, M. D. (2008). Why are we shaped differently, and why does it matter?. *American Journal of Physiology-Endocrinology and Metabolism*, *295*(3), E531-E535.

Schoenfeld, B. J. (2010). The mechanisms of muscle hypertrophy and their application to resistance training. *The Journal of Strength & Conditioning Research*, *24*(10), 2857-2872.

Schroeder, E. C., Franke, W. D., Sharp, R. L., & Lee, D. C. (2019). Comparative effectiveness of aerobic, resistance, and combined training on cardiovascular disease risk factors: A randomized controlled trial. *PloS one*, *14*(1), e0210292.

Scott, B. R., Loenneke, J. P., Slattery, K. M., & Dascombe, B. J. (2016). Blood flow restricted exercise for athletes: A review of available evidence. *Journal of science and medicine in sport*, *19*(5), 360-367.

Shepherd, J. A., Ng, B. K., Sommer, M. J., & Heymsfield, S. B. (2017). Body composition by DXA. *Bone*, *104*, 101-105.

Sillanpää, E. L. I. N. A., Häkkinen, A. R. J. A., Nyman, K., Mattila, M., Cheng, S., Karavirta, L., ... & Häkkinen, K. E. I. J. O. (2008). Body composition and fitness during strength and/or endurance training in older men. *Medicine and science in sports and exercise*, *40*(5), 950-958.

Sillanpää, E., Laaksonen, D. E., Häkkinen, A., Karavirta, L., Jensen, B., Kraemer, W. J., ... &

Häkkinen, K. (2009). Body composition, fitness, and metabolic health during strength and endurance training and their combination in middle-aged and older women. *European journal of applied physiology*, *106*(2), 285-296.

Sousa, N., Mendes, R., Abrantes, C., Sampaio, J., & Oliveira, J. (2013). A randomized 9-month study of blood pressure and body fat responses to aerobic training versus combined aerobic and resistance training in older men. *Experimental gerontology*, *48*(8), 727-733.

Spranger, M. D., Krishnan, A. C., Levy, P. D., O'Leary, D. S., & Smith, S. A. (2015). Blood flow restriction training and the exercise pressor reflex: a call for concern. *American Journal of Physiology-Heart and Circulatory Physiology*, *309*(9), H1440-H1452.

Stewart, K. J., Bacher, A. C., Turner, K. L., Fleg, J. L., Hees, P. S., Shapiro, E. P., ... & Ouyang, P. (2005). Effect of exercise on blood pressure in older persons: a randomized controlled trial. *Archives of internal medicine*, *165*(7), 756-762.

Suga, T., Okita, K., Morita, N., Yokota, T., Hirabayashi, K., Horiuchi, M., ... & Tsutsui, H. (2009). Intramuscular metabolism during low-intensity resistance exercise with blood flow restriction. *Journal of Applied Physiology*, *106*(4), 1119-1124.

Suga, T., Okita, K., Morita, N., Yokota, T., Hirabayashi, K., Horiuchi, M., ... & Tsutsui, H. (2010). Dose effect on intramuscular metabolic stress during low-intensity resistance exercise with blood flow restriction. *Journal of applied physiology*, *108*(6), 1563-1567.

Suga, T., Okita, K., Takada, S., Omokawa, M., Kadoguchi, T., Yokota, T., Hirabayashi, K., Takahashi, M., Morita, N., Horiuchi, M., Kinugawa, S., & Tsutsui, H. (2012). Effect of multiple set on intramuscular metabolic stress during low-intensity resistance exercise with blood flow restriction. *European journal of applied physiology*, *112*(11), 3915–3920. https://doi.org/10.1007/s00421-012-2377-x

Tagawa, K., Ra, S. G., Kumagai, H., Yoshikawa, T., Yoshida, Y., Takekoshi, K., ... & Maeda, S. (2018). Effects of resistance training on arterial compliance and plasma endothelin-1 levels in healthy men. *Physiological research*, *67*.

Takada, S., Okita, K., Suga, T., Omokawa, M., Kadoguchi, T., Sato, T., ... & Tsutsui, H. (2012). Low-intensity exercise can increase muscle mass and strength proportionally to enhanced metabolic stress under ischemic conditions. *Journal of applied physiology*, *113*(2), 199-205.

Takarada, Y., Nakamura, Y., Aruga, S., Onda, T., Miyazaki, S., & Ishii, N. (2000). Rapid increase in plasma growth hormone after low-intensity resistance exercise with vascular occlusion. *Journal of applied physiology*, *88*(1), 61-65.

Takarada, Y., Sato, Y., & Ishii, N. (2002). Effects of resistance exercise combined with vascular occlusion on muscle function in athletes. *European journal of applied physiology*, *86*(4), 308-314.

Vechin, F. C., Libardi, C. A., Conceição, M. S., Damas, F. R., Lixandrão, M. E., Berton, R. P., ... & Ugrinowitsch, C. (2015). Comparisons between low-intensity resistance training with blood flow restriction and high-intensity resistance training on quadriceps muscle mass and strength in elderly. *The Journal of Strength & Conditioning Research*, *29*(4), 1071-1076.

Vina, J., Sanchis□Gomar, F., Martinez□Bello, V., & Gomez□Cabrera, M. C. (2012). Exercise acts
as a drug; the pharmacological benefits of exercise. *British journal of pharmacology*, *167*(1), 1-12.

Vincent, K. R., Vincent, H. K., Braith, R. W., Bhatnagar, V., & Lowenthal, D. T. (2003). Strength training and hemodynamic responses to exercise. *The American journal of geriatric cardiology*, *12*(2), 97-106.

Wewege, M. A., Desai, I., Honey, C., Coorie, B., Jones, M. D., Clifford, B. K., ... & Hagstrom, D. (2021). The effect of resistance training in healthy adults on body fat percentage, fat mass and visceral fat: a systematic review and meta-analysis. *Sports Medicine*, 1-14.

Wilkinson, I. B., MacCallum, H., Flint, L., Cockcroft, J. R., Newby, D. E., & Webb, D. J. (2000). The influence of heart rate on augmentation index and central arterial pressure in humans. *The Journal of physiology*, *525*(Pt 1), 263.

Wilkinson, I. B., MacCallum, H., Cockcroft, J. R., & Webb, D. J. (2002). Inhibition of basal nitric oxide synthesis increases aortic augmentation index and pulse wave velocity in vivo. *British journal of clinical pharmacology*, *53*(2), 189-192.

Wilson, J. M., Marin, P. J., Rhea, M. R., Wilson, S. M., Loenneke, J. P., & Anderson, J. C. (2012). Concurrent training: a meta-analysis examining interference of aerobic and resistance exercises. *The Journal of Strength & Conditioning Research*, *26*(8), 2293-2307.

Yasuda, T., Fujita, S., Ogasawara, R., Sato, Y., & Abe, T. (2010). Effects of low□intensity bench
press training with restricted arm muscle blood flow on chest muscle hypertrophy: a pilot study. *Clinical physiology and functional imaging*, *30*(5), 338-343.

Yasuda, T., Ogasawara, R., Sakamaki, M., Ozaki, H., Sato, Y., & Abe, T. (2011a). Combined effects of low-intensity blood flow restriction training and high-intensity resistance training on muscle strength and size. *European journal of applied physiology*, *111*(10), 2525-2533.

Yasuda, T., Ogasawara, R., Sakamaki, M., Bemben, M. G., & Abe, T. (2011b). Relationship between limb and trunk muscle hypertrophy following high□intensity resistance training and blood flow–restricted low□intensity resistance training. *Clinical physiology and functional imaging*, *31*(5), 347-351.

Yasuda, T., Fukumura, K., Fukuda, T., Uchida, Y., Iida, H., Meguro, M., ... & Nakajima, T. (2014). Muscle size and arterial stiffness after blood flow□restricted low□intensity resistance training in older adults. *Scandinavian journal of medicine & science in sports*, *24*(5), 799-806.

Yoshizawa, M., Maeda, S., Miyaki, A., Misono, M., Saito, Y., Tanabe, K., ... & Ajisaka, R. (2009). Effect of 12 weeks of moderate–intensity resistance training on arterial stiffness: a randomised controlled trial in women aged 32–59 years. *British journal of sports medicine*, *43*(8), 615-618.

Zoungas, S., & Asmar, R. P. (2007). Arterial stiffness and cardiovascular outcome. *Clinical and experimental pharmacology & physiology*, *34*(7), 647–651. https://doi.org/10.1111/j.1440-1681.2007.04654.x

APPENDIX

APPENDIX

DEFINITIONS

Arterial compliance – the measurement of the elastic properties of the arteries; inverselyrelated to arterial stiffness

Blood Flow Restriction – an exercise technique using pneumatic cuffs to restrict venousreturn during exercise

Body composition – used as a description of fat tissue, lean tissue, and bone tissue in the human body

Hemodynamics – Analysis of the physical aspects of blood circulation

Maximal Voluntary Contraction – the maximal force-generating capacity of a muscle or muscle group

PAR-Q - Physical activity readiness questionnaire; a screening tool that is designed todetermine exercise participation

Pulse Wave Velocity – Noninvasive measuring technique of arterial compliance; can bemeasured centrally or peripherally

LIST OF ABBREVIATIONS

AIx – Augmentation Index

Aix@75 – Augmentation Index Normalized at 75 bpm

ANCOVA – Analysis of Covariance

ANOVA – Analysis of Variance

BFR – Blood Flow Restriction

BPM– Beats Per Minute

DBP – Diastolic Blood Pressure

SBP – Systolic Blood Pressure

iDXA – Dual-Energy X-ray Absorptiometry

HR – Heart Rate

MAP – Mean Arterial Pressure

SAE – Small Arterial Elasticity

SVR – Systemic Vascular Resistance

SV – Stroke Volume

HI-RT – High-intensity resistance training

HI+AE - High-intensity resistance training combined with aerobic exercise

1RM – One-repetition maximum

PP – Pulse Pressure

mmHg – Millimeters of Mercury

MVC – Maximal Voluntary Contraction

PP – Aortic Pulse Pressure

PWV – Pulse Wave Velocity

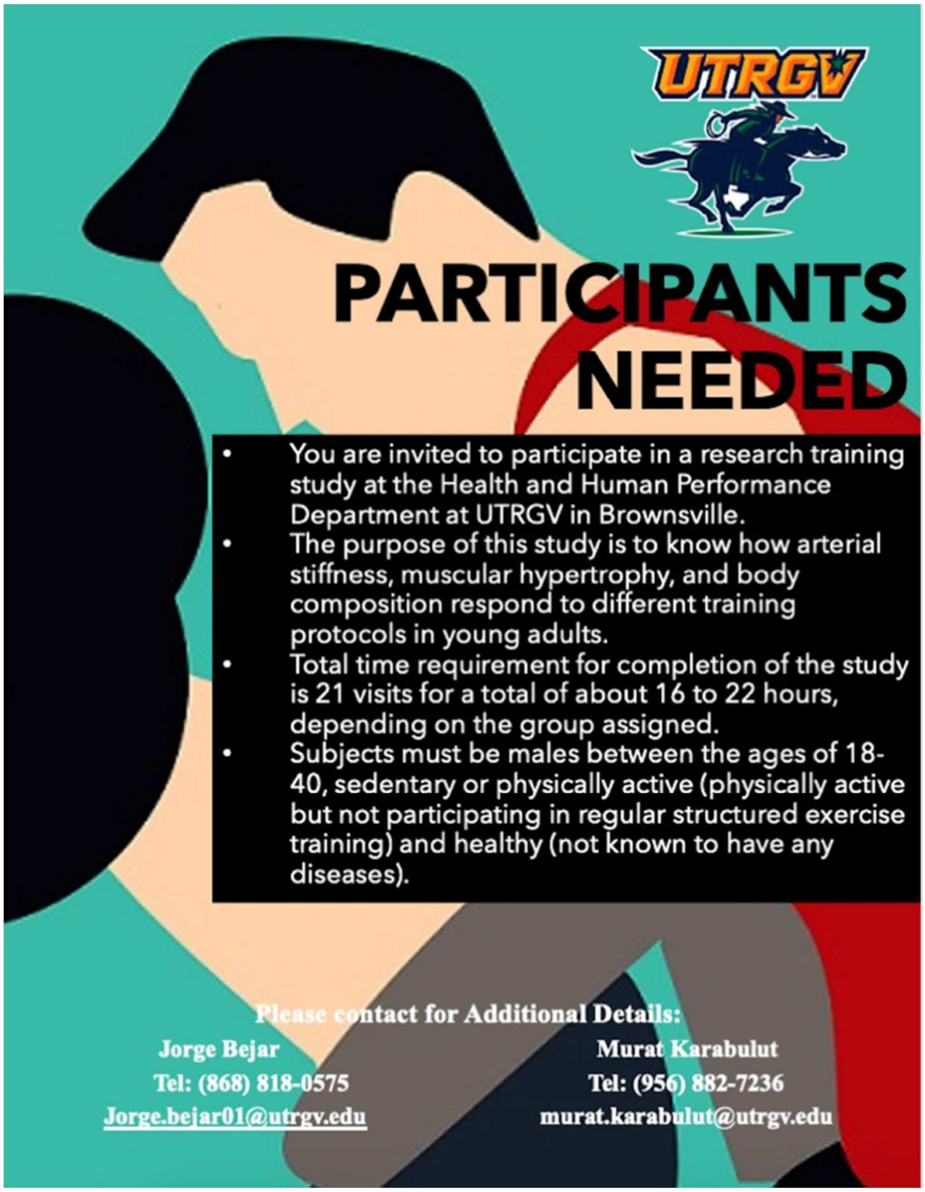
LAE – Large Arterial Elasticity

SPSS – Statistical Package for the Social Sciences

USG – Urine Specific Gravity

FILES

1. RECRUITMENT FLYER



2. INFORMED CONSENT

The University of Texas
Rio Grande Valley

INFORMED CONSENT FORM AND HIPAA AUTHORIZATION

Study Title: Arterial Stiffness, Muscular Hypertrophy, and Body Composition Response to Different Training Protocols in Young Adults.

Consent Name: RESEARCH STUDY PARTICIPATION CONSENT FORM

Principal Investigator:	Dr. Murat Karabulut	**Telephone:** (956) 882-7236
Co-Investigators:	Jorge Bejar	**Telephone:** (868) 818-0575
Other Study Personnel:	Megan Zamora, Alexis Lopez, Antonio Vargas	
Department:	Health and Human Performance	
Emergency Contact:	Dr. Murat Karabulut	Telephone: (956) 882-7236

Key points you should know

- We are inviting you to be in a research study we are conducting. Your participation is voluntary. This means it is up to you and only you to decide if you want to be in the study. Even if you decide to join the study, you are free to leave at any time if you change your mind.
- Take your time and ask to have any words or information that you do not understand explained to you.
- We are doing this study because we want to learn
    - This study will be conducted to compare the effects of different resistance training or weight training protocols [1) low-load weight training with blood flow restriction (BFR) (which is a technique that restricts venous blood return during exercise by placing specifically designed cuffs over target limbs and inflating them to a pressure that has been set beforehand.) in combination with moderate intensity aerobic training. 2) Traditional high intensity weight training. 3) Traditional high intensity weight training in combination with moderate intensity aerobic training with blood flow restriction (BFR). 4) A control group which will not do any type of resistance training, and will only be present for pre-training, mid-training, and post-training measures.] on adaptations in arterial stiffness, adaptations in the muscles and body composition in young adults.

- **Why are you being asked to be in this study?**
  - You are being asked to participate in this study, because you meet the following qualification criteria: males between the ages of 18-40, sedentary or physically active (physically active but not participating in regular structured exercise training) and healthy (not known to have any diseases).
  - But will be excluded if you are diagnosed with diseases (e.g. Diabetes, heart disease, etc.), have other musculoskeletal injury impairing physical performance, have history of blood clots, varicose veins, deep vein thrombosis (DVT), or other conditions that would impede venous return.
- **What will you do if you agree to be in the study?**

- Participate in an 8-week training program and laboratory visits.
- A total of 21 sessions is required
- Depending on the group assigned, total time commitment is about 16 to 22 hours.
- All study procedures will be conducted in the Exercise Science Laboratory (M-1 building, room 216), Training Room (Cortez Hall, Room 224) and DXA scan will be performed in Cortez Hall, room 214.
- The study personnel and participants will follow current COVID guidelines as recommended by the CDC.
- You will also have to sign a log with date and time every time before entering and leaving the facility.
- You will fill out "PAR-Q", "health status questionnaire", and "questionnaire to identify individuals with diseases affecting venous return", be familiarized with the study procedures, and will carefully read and sign an informed consent before any testing takes place.
- If you do not fullfill required criteria set in the study you will be excluded from this study.
- The procedure will maintain a schedule as follows:
  - Session 1: Paperwork, Questionnaires, informed consent.
  - Session 2: Anthropometric measurements (height and weight), DXA scan, Electromyography + Biodex , One-repetition maximum testing.
  - Session 3: Heart and blood vessels parameter recording, VO2 max testing.
  - Session 4-19: High Intensity Group – Traditional weight training session
    Low Intensity BFR Group – Weight training with BFR session followed by aerobic training with BFR.
    High Intensity BFR Group – Traditional weight training session followed by aerobic training with BFR.
  - Session 20: Fasted and hydrated laboratory visit for testing mirroring session 2
  - Session 21: Fasted and hydrated laboratory visit for testing mirroring session 3
- Following initial screening (based on questionnaire designed to determine whether or not you are eligible to participate in the study), for the laboratory visits, you will be required to be fasted (for at least 8 hours) and hydrated. You are required to provide

urine samples for monitoring Hydration (urine refractometer will check the sample and the level of current hydration. Hydration must be at or below 1.010).

- 4 urine samples are required over a period of 8-weeks. Urine samples will not be stored and will be disposed of immediately after analysis in a biohazard water container.
- Anthropometric measurements (height, weight and mid-thigh circumference) will be taken next.
- Measurements related to the heart and blood vessels will be recorded by using SphygmoCor, which uses non-invasive arterial tonometry. The pressure waveforms and amplitudes are going to be obtained from an artery with a pencil-type probe incorporating a sensor. The data will be recorded for pre-training and post-training. Measurements will be performed for sessions 3 and 21.
- Before beginning the test, you will rest lying facing upwards for a minimum of 5 minutes.
- During the procedure you will remain lying until the research team prepares all data collection materials to collect and record data during each session.
- Calibration of the equipment will be performed regularly according to instructions provided by the manufacture.
- Body composition will be measured using the *dual*-energy *x-ray absorptiometry* (DXA, gold standard for body composition*)* will be performed before training, after 4 weeks of training, and after the training program is complete.
- Biodex (a computer assisted machine that is used to assess muscle strength, power, etc.) and Electromyography (EMG) (a technique of placing non-invasive electrodes on skin to record electrical activity of muscle during contraction) will be used in tandem to measure muscle recruitment and strength using a variety of tests. The data will be recorded before beginning training, and after weight training ends.
- After that you will warm up for 5 minutes in a treadmill and then perform 1-repetition maximum (the maximum load that can be lifted only once with proper technique) on the leg curl, leg extension, leg press, incline bench press, shoulder press, and lat pulldown. The data will be recorded before beginning training and after weight training ends.
- The next test will be a treadmill VO2 max test. This test will be performed until exhaustion, and will consist of multiple stages in which treadmill speed and inclination will increase in order to obtain VO2max. VO2max will be obtained using a formula that uses test duration to assess maximum oxygen consumption.
- The weight training will take place over an 8-week period.
- You will come to and perform the specified routine 2 times a week with at least 48 hours of rest between sessions.
- You will perform two different types of resistance training called Low-intensity BFR training and Traditional high-intensity resistance training.
- Methods practiced in previous studies will be used to determine proper pressure for the BFR cuffs depending on your musculature and circumference of the limbs.
- Subjects in the Low-intensity BFR group will also perform aerobic training in a cycle ergometer.

- Session 3-14 and 16-27

  Traditional High Intensity Group: will include the weight training sessions in which you will come to the training room and perform the specified routine 2 times a week with at least 48 hours of rest between sessions.

Low Intensity BFR Group: will include the weight training sessions with BFR in which you will come to the training room and perform the specified routine 2 times a week with at least 48 hours of rest between sessions. Resistance training will be followed by moderate intensity aerobic training with BFR in a treadmill.

Traditional High Intensity BFR Group: will include the weight training sessions in which you will come to the training room and perform the specified routine 2 times a week with at least 48 hours of rest between sessions. Resistance training will be followed by moderate intensity aerobic training with BFR in a treadmill.

- You will be randomly assigned to one of the three groups performing one of the designed resistance training for a total of 8 weeks, 2 times a week.
- You will perform these sessions under the supervision of the investigators.
- The training sessions, will look as follows:
    - The LI-BFR weight training will begin with the you warming up with a mild jog for 5 minutes. BFR cuffs will be applied to your arms and legs and will be raised to the calculated pressure following established protocol. You will then perform the training routine which consists of 6 exercises (leg press, leg curl, leg extension, incline bench press, lat pulldown, and shoulder press) of which there will be 4 sets performed for 20 reps each set all at an intensity of 20-40% of your maximum load. You will rest 30-60 seconds between each set and 3 minutes between each exercise. Following the resistance training session, you will perform a 10 to 15-min walking/jogging exercise at 60% of heart rate maximum.
    - The high-intensity weight training will begin with you warming up by doing a mild jog for 5 minutes. You will then perform the training routine which consists of 6 exercises (leg press, leg curl, leg extension, incline bench press, lat pulldown, and shoulder press) at an intensity of 80% of 1 your maximum load. You will perform 3 sets consisting of 8 - 11 repetitions. You will rest 2 minutes between each set and 3 minutes between each exercise.
    - The traditional high-intensity weight training in combination with aerobic BFR will begin with you warming up by doing a mild jog for 5 minutes. You will then perform the training routine which consists of 6 exercises (leg press, leg curl, leg extension, incline bench press, lat pulldown, and shoulder press) at an intensity of 80% of 1 your maximum load. You will perform 3 sets consisting of 8 - 11 repetitions. You will rest 2 minutes between each set and 3 minutes between each exercise. Following the resistance training session, you will perform a 10 to 15-min walking/jogging exercise with BFR at 60% of heart rate maximum.

- Blood flow restriction will be implemented by putting on specialized cuffs filled with air (similar to blood pressure measuring cuffs) in the uppermost portion of the thighs and arms. The pressure on the cuffs will be maintained by a specialized air pressure controlling machine. The cuffs will be applied your upper thighs and arms before the beginning exercises and will be deflated or put off when you finish the exercises. It will take about 15-20 minutes.

- The initial pressure of the cuffs will be 30-50 mmHg. The final pressure on the cuffs will be based on established overload and progression of exercise training guidelines and will vary during sessions. The final pressure usually varies from 120-220 mm Hg. The appropriate final pressure in the cuffs at the training day will be determined by the supervising researcher. The researcher will check the vascularity or circulation of the restricted limbs by a method called "capillary refill time" and determine the appropriate final pressure. According to previous research studies, capillary refill time has been recognized as a potential means of assessing peripheral circulation (assessing cardiac output and peripheral vascular resistance) and <3.5 sec is considered normal. Furthermore, previous research studies have used this technique regarding determining the pressure used of BFR cuffs. Therefore, the cuff pressure will be set when the capillary refill time is between 1 and 3 seconds to ensure the necessary circulation to the restricted limb.
- You will not be medically supervised during this study.
- You will be responsible for the cost of any care or injuries.

- **Can you be harmed by being in this study?**
    - Being in this study involves no greater risk than what you ordinarily encounter in daily life.
    - However, you must understand there are always minimal risks to healthy individuals when performing any of the requirements for this project.
    - Even though these standard protocols have been approved at numerous other institutions and will be performed by qualified and trained personnel, it should be noted that this study has the following risks:
    - **Risks associated with Physical and major changes in exercise:** Exercise stress or any form of physical activity is considered minimal risk and can result in muscle soreness.
    - **Risks associated with collection of urine samples:** The physical risks of these procedures are all minimal.
    - **Risks associated with use of BFR cuffs:** Minimal physical discomfort can result due to use of blood flow restriction cuffs.
    - **Risks associated with use of approved devices:** The devices used in this study are non-invasive, meaning they are not introduced into the body. They are scientifically approved and used in a lot of previous research studies. The physical risk of these devices is minimal.
    - **Risk of radiation:** There is always a risk from exposure to radiation. However, the amount of radiation used in DXA scan is extremely small. The amount of radiation exposed to in Annual Natural Background Exposure is 2400 uSv and in a Chest X-Ray is 50 uSv. However, a DXA test exposure is only 0.6 uSv, less than one-tenth the dose of a standard chest x-ray. DXA scan will be conducted by trained personnel that are certified and approved by the Radiation Safety Department. For other queries about radiation risk, please consult with your personal physician.

- **Risks to your personal privacy and confidentiality:** The measurements collected in this study are for research purposes, not for diagnosing any health problems. Research that uses physiological information can affect your privacy. Your participation in this research will be held strictly confidential and only a code will be used to identify your stored data. However, because there will be a link between the code and your identity, confidentiality cannot be guaranteed. The test results for this research purpose will not be shared with you.
- There may be other risks that are not known at this time. Tell the study investigator or study staff right away if you have any problems.

- Will you get anything for being in this study?
  - There are no costs for participation in this study. Participation is voluntary, and you will not receive any payments for taking part of this study. If you decline to participate, 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.
  - The benefits to participation are: You will receive information about your anthropometric measurements (height and weight), body composition (fat mass, fat-free mass, bone mineral density) and cardiovascular health, such as: resting blood pressure, resting heart rate, and arterial health. You will also obtain information about your cardiovascular health and arterial health from Pulse Wave Analysis assessment. Lastly, you will obtain free personal resistance training, which will help you maintain healthy bones, muscles and joints and hopefully improve your quality of life.

- Could you be taken out of the study?
  - If you miss 3 consecutive sessions, which equals more than one week of training, you will automatically be disqualified and removed from the study as the changes of the exercise training will be lost.

Can the information we collect be used for other studies?

Information that could identify you will be removed and the information you gave us may be used for future research by us or other researchers; we will not contact you to sign another consent form if we decide to do this.

What else should you know?

- We are asking 40 people to be in this study.

- Research tests using your sample and physiological data may possibly result in inventions or procedures that have commercial value and are eligible for protection by a patent. By agreeing to the use of your sample in research, you are giving your sample without expectation of acknowledgment, compensation, interest in any commercial value or patent, or interest of any other type. However, you retain your legal rights during your participation in this research.
- The measurements collected are for research purposes not for diagnosing any health problems. We will not be sharing our findings with you; this means that we will not contact you to tell you your individual results.
- The amount of radiation used in DXA scan is extremely small. The amount of radiation exposed to in Annual Natural Background Exposure is 2400 uSv and in a Chest X-Ray is 50 uSv. However, a DXA test exposure is only 0.6 uSv, less than one-tenth the dose of a standard chest x-ray.
- We will not be sharing our findings with you: this means that we will not contact you to tell you your individual results.

How will your information be used and shared?

- If you agree to be in this research study and sign this consent form, you give your permission to: Dr. Murat Karabulut, Jorge Bejar, Megan Zamora, Alexis Lopez, and Antonio Vargas to use or share your health information for this research study.
- Information that could identify you will be removed and the information you gave us may be used for future research by us or other researchers; we will not contact you to sign another consent form if we decide to do this.
- No details about the process and what information would be shared will be provided to you or your physician.
- We will do our best to make sure your information stays private. Let us know if you have questions about this.
- If you have any questions about the Privacy Rule you can speak to the investigator or the Privacy Officer at 956-296-1424.

What happens if I say no or change my mind?

- You can say you do not want to be in the study now or if you change your mind later you can stop participating at any time.
- We will not collect, use, or share your information for this study.
- No one will treat your differently. You will not be penalized.

How will my privacy be protected?

- We will only share your information with approved personnel from the University of Texas at Rio Grande Valley.
- Your information will be stored with a code instead of identifiers (such as name, date of birth, email address, etc.) in a cabinet for 3 years and after that it will be shredded.
- Even though we will make efforts to keep your information private, we cannot guarantee confidently because it is always possible that someone could figure out a way to find out what you do on a computer.
- No published scientific reports will identify you directly.

Who is paying for this study?

- The Department of Health and Human Performance at The University of Texas Rio Grande Valley is funding this research.

What should you do if you are hurt or injured during this study?

- In case of injury or illness resulting from this study, emergency medical services will be contacted as soon as possible by calling (956)-882-3896 or 911.
- The University of Texas Rio Grande Valley does not offer financial compensation or payment for injuries due to participation in this research.
- If medical assistance is needed, you and your insurance company will be billed for the costs of any care or injuries.
- In case of injury resulting from this study, you will not lose any legal rights by signing this form.

Who to Contact Regarding Your Rights as a Participant?

This research has been reviewed and approved by the University of Texas Rio Grande Valley Institutional Review Board for Human Subjects Protections (IRB). If you have any questions about your rights as a participant, or if you feel that your rights as a participant were not adequately met by the researcher, please contact the IRB at (956) 665-3598 or irb@utrgv.edu.

Signatures

By signing below, you indicate that you are voluntarily agreeing to participate in this study and that the procedures involved have been described to your satisfaction. The researcher will provide you with a copy of this form for your own reference. In order to participate, you must be at least 18 years of age. If you are under 18, please inform the researcher.

______________________________________ ____/_____/_____

Participant's Signature Date

3. PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

2021 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

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

GENERAL HEALTH QUESTIONS

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

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

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://www.who.int/publications/i/item/9789240015128).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ____________________ DATE ____________

SIGNATURE ____________________ WITNESS ____________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____________________

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

Delay becoming more active if:

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

 1 / 4
01-11-2020

4. HEALTH STATUS QUESTIONNAIRE

University of Texas at Rio Grande Valley

Health Status Questionnaire

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

Part 1. Information About The Individual

1. Date__________________
2. Legal Name_______________________Nickname___________________________
3. Mailing Address____
   ____
4. Home Phone _________________________Business Phone__________________________
5. Personal Physician Phone _____________________
6. Person to Contact in Emergency Phone _____________________
7. Preferred Hospital in Case of Emergency _______________________
8. Gender (Circle One): Female Male
9. Date Of Birth: ____/_____/_______ Month/Day/Year
10. Number of hours worked per week:
    Less than 20 20-40 41-60 Over 60
11. More than 25% of time on job is spent (Circle all that apply):
    Sitting at desk Lifting or carrying loads Standing Walking Driving

Part 2. Medical Information

12. Circle any who died of heart attack before age 50:
    Father Mother Brother Sister Grandparent
13. Date of last medical physical exam: _______________(Year)

14. Last physical fitness test: ____________________(Year)

15. Circle operations you have had:

Back	Heart	Kidney	Eyes	Joint	Neck
Ears	Hernia	Lung	Other__________________________		

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

Alcoholism	Cirrhosis, Liver	Hearing Loss	Neck Strain
Anemia, Sickle Cell	Concussion	Heart Problem	Obesity
Anemia, Other	Congenital Defect	High Blood Pressure	Phlebitis
Asthma	Diabetes	Hypoglycemia	Rheumatoid Arthritis
Back Strain	Emphysema	Hyperlipidemia	Stroke
Bleeding Trait	Epilepsy	Infectious Mononucleosis	Thyroid Problem
Bronchitis, Chronic	Eye Problems	Kidney Problem	Ulcer
Cancer	Gout	Mental Illness	

Other____

14. Circle all medicine taken in last 6 months:

Blood Thinner	Diuretic	High Blood Pressure Medication
Diabetic Pill	Epilepsy Medication	Insulin
Digitalis	Heart-Rhythm Medication	Nitroglycerin

Other____

15. These health symptoms may require medical attention if they occur frequently. Circle the number indicating how often you have each of the following:

5: Very Often 4: Fairly Often 3: Sometimes 2: Infrequently 1: Practically Never

a. Cough up blood	d. Leg pain	g. Swollen joints
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
b. Abdominal pain	e. Arm or shoulder pain	h. Feel faint

1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
c. Low back pain	f. Chest pain	i. Dizziness
1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
j. Breathless with slight exertion		
1 2 3 4 5		

Part 3. Health-Related Behavior

16. Do you now smoke? (Circle one) Yes No

17. 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, non inhaled

18. Do you exercise regularly? (Circle one) Yes No

19. How many days per week do you normally spend at least 20 minutes in moderate to strenuous exercise?

0 1 2 3 4 5 6 7 days per week

20. Can you walk 4 miles briskly without fatigue? (Circle one) Yes No

21. Can you jog 3 miles continuously at a moderate pace without discomfort? (Circle one) Yes No

22. Weight now__________ lb. One year ago_____________ lb. Age 21________ lb.

23. List everything not already included on this questionnaire that might cause you problems in a fitness test or fitness program:

____
____
____

5. VENOUS RETURN QUESTIONNAIRE

Questionnaire to Identify Individuals with Diseases Affecting Venous Return

Name: **Date:**

DOB:

1. Do you experience any of the following symptoms? (Circle your answers)		
a. Aching/ throbbing/ pain in your legs?	Yes	No
b. Heaviness in your legs?	Yes	No
c. Swollen ankles/legs?	Yes	No
2. Have your veins gotten worse in recent months?	Yes	No
If yes, explain:		
3. Do you wear support stockings/compression socks?	Yes	No
If YES:		
a. Were they prescribed by a doctor?	Yes	No
b. Do they provide relief?	Yes	No
c. How long have you been wearing them consistently?		
4. Do you have problems with walking due to vein pain?	Yes	No
5. Have you ever had any tests or procedures done on your veins?	Yes	No
If yes, when, what type of test/procedure and what location on the leg?		
6. Have you been diagnosed with blood clotting diseases, deep vein thrombosis (DVT), superficial vein thrombosis, varicose veins, or other conditions that would impede venous return?	Yes	No
If yes, explain:		
7. Were you prescribed any medication for abovementioned diseases?	Yes	No
If YES:		
a. Were they prescribed by a doctor?	Yes	No
b. Do they provide relief?	Yes	No
c. How long have you been taking them consistently?	Yes	No
d. Provide the name of medication		

6. DATA SHEET

Session:

Name: ___________________________ **Date:**_______________

Height: ______________ **Weight:** ____________

Hydration Value: ___________ **DOB:** _____________

Cycle Ergometer Height: _______

Biodex Measurements:

Chair Front/Back	
Chair Height	
Dynamometer Left/Right	
Attachment Length	
Seat Forward/Back	
Finger Width	

Biodex Testing:

Test	Trial	N/m
MVC	1	
	2	
	3	
ISO 60	1	
	2	
ISO 180	1	
	2	

1 RM Testing:

Exercise	1 RM	Adjustment
Leg Press		
Leg Extension		
Leg Curl		
Incline Bench Press		
Lat Pulldown		
Shoulder Press		

Session:

Hydration Value: ___________

Sphygmocor:

Pulse Wave Analysis	Trial 1	Trial 2	Trial 3
Systolic Pressure			
Diastolic Pressure			
Pulse Pressure			
Mean Arterial Pressure			
AIx			
AIx75			
Heart Rate			

Site	Value (mm)
Femoral to Cuff	
Carotid to Sternal Notch	
Sternal Notch to Cuff	

Test	Trial	Value (m/s)
Pulse Wave Velocity	1	
	2	
	3	
	4	

VO2 Max Testing:

Bruce Protocol	Speed	Incline	Time	HR	RPE
Stage 1	1.7 mph	10%	0-3 min		
Stage 2	2.5 mph	12%	3-6 min		
Stage 3	3.4 mph	14%	6-9 min		
Stage 4	4.2 mph	16%	9-12 min		
Stage 5	5.0 mph	18%	12-15 min		

Total Duration	

MAX HR:

WEIGHT TRAINING

SESSION #:

BFR / TRADITIONAL

Expected HR:

Leg Press

1 RM:

Trial Load:

Sets	Reps	Load (lbs)	HR	RPE
1				
2				
3				
4				

Leg Extension

1 RM:

Trial Load:

Sets	Reps	Load (lbs)	HR	RPE
1				
2				
3				
4				

Leg Curl

1 RM:

Trial Load:

Sets	Reps	Load (lbs)	HR	RPE
1				
2				
3				
4				

Incline Bench Press

1 RM:

Trial Load:

Sets	Reps	Load (lbs)	HR	RPE
1				
2				
3				
4				

Lat Pulldown

1 RM:

Trial Load:

Sets	Reps	Load (lbs)	HR	RPE
1				
2				
3				
4				

Shoulder Press

1 RM:

Trial Load:

Sets	Reps	Load (lbs)	HR	RPE
1				
2				
3				
4				

AEROBIC SESSION

Treadmill Speed:
Grade:

Min	HR	RPE
5		
10		
15		

Researcher Notes

- ❑ Initial pressure on leg should be around 35-45 mmHg
- ❑ **Leg Initial Pressure**
  Left:
  Right:
- ❑ **Leg Final Pressure**
  mmHg:
- ❑ **Arm Initial Pressure**
  Left:
  Right:
- ❑ **Arm Final Pressure:**
  mmHg:

BIOGRAPHICAL SKETCH

Jorge Bejar received his BS in Exercise Science in May 2020. He received his MS in Exercise Science in August 2022. Both degrees acquired from The University of Texas Rio Grande Valley in Brownsville, Tx. george_bejar@hotmail.com; jorge.bejar01@utrgv.edu