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The Effects of a Short-Term Endurance Training Program with Blood Flow Restriction Cuffs Versus ACSM Recommended Endurance Training on Arterial Compliance and Muscular Adaptations in Recreationally Active Males

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THE EFFECTS OF A SHORT-TERM ENDURANCE TRAINING PROGRAM WITH BLOOD FLOW RESTRICTION CUFFS VERSUS ACSM RECOMMENDED ENDURANCE TRAINING ON ARTERIAL COMPLIANCE AND MUSCULAR ADAPTATIONS IN RECREATIONALLY ACTIVE MALES

A Thesis

by

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THE EFFECTS OF A SHORT-TERM ENDURANCE TRAINING PROGRAM WITH BLOOD FLOW RESTRICTION CUFFS VERSUS ACSM RECOMMENDED ENDURANCE TRAINING ON ARTERIAL COMPLIANCE AND MUSCULAR ADAPTATIONS IN RECREATIONALLY ACTIVE MALES

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ABSTRACT

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RESULTS: Significant time and group interaction found in cardiac ejection time ($p<.05$). Significant condition difference between blood flow restriction (BFR) and control for heart rate (HR) max ($p=.05$) and maximum oxygen consumption (VO_2) ($p<.05$). Significant time difference found in pulse wave velocity femoral to distal ($p<.05$). Significant repetition main effect ($p<.01$) for root mean square (RMS) and median frequency (MDF) of Thorstensson. Significant time and group interaction in vastus lateralis of MDF ($p<.01$). Significant repetition main effect for RMS and MDF ratio ($p<.01$) Significant time and repetition interaction in vastus lateralis of RMS ratio ($p<.03$)

CONCLUSION: The BFR session showed improvement in both post HR max and post VO_2 in comparison to the control group. This may have been caused by increased tolerance to pain/metabolic by-products for HR and increased efficiency at extracting oxygen for VO_2.

KEYWORDS: Blood flow restriction, arterial elasticity, pulse wave velocity, electromyography, endurance.

DEDICATION

This thesis is dedicated to my parents for always making education a priority when raising me. I wouldn't be where I am today without your support and for making me feel like I could always achieve more in life. To Jb and Yaya Corbeil, thank you for always giving me a place to decompress and for being amazing friends. To Tyler Oliveira, thank you for always believing in me, even when I didn't.

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A great thanks goes out to the people that I met during the past two years of grad school, who over the months of class, papers and exams became my friends. Margarita Gonzalez, even though we're close in age you became an awesome mentor, teacher for basically all the equipment in the lab, and most importantly a friend. You were the person I could go to when the sky was falling because the sky had fallen on you too. Juan Paredes, you were always there to give me a laugh even if I was the joke, humility is key. Your comedic relief in class was always the best and you made me feel better knowing that a diet of wheat, barley and hops is acceptable when you have several Imaynotmakeitoutalive finals. Magalie Sanchez, you gave me some of the best wise-beyond-your-age unexpected advice (I guess it's an only child thing) when I needed it the most. You were always incredibly supportive of everything I did, and were the cheerleader in my corner that I needed to get through the hard times.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER I

INTRODUCTION

Research has shown that "arterial stiffness is an independent predictor of mortality and is regulated by a number of factors including vascular smooth muscle tone" (Mc Eniery et al., 2006). Both in animals and humans "arterial stiffness is closely related with both left ventricular (LV) and systolic and diastolic dysfunction" (Tsao et al., 2015, p.1). It is a major factor that leads to "cardiovascular disease and is becoming a focal point in the efforts of early detection and prevention of cardiovascular disease" (Sugawara et al., 2005). One way to combat coronary artery disease (CAD) and maintain cardiovascular fitness in healthy adults according to the American College of Sports Medicine (ACSM) guidelines for aerobic training, is to exercise 3 to 5 days a week for approximately 60 minutes (Abe et al., 2010, p.34). Edwards, Schofield, Magyari, Nichols, and Braith (2004) found that "exercise training appears to be associated with reduced arterial stiffness or increased compliance" (p.540).

In a 12-week training program, Edwards et al. (2004) examined the effects of endurance exercise training in patients with CAD. The results showed a reduction in arterial stiffness as evidenced by a reduction in augmentation index (30% at baseline *v* 26% at 12weeks). In 2003, Oliver and Webb stated that "there are several non-invasive methods for arterial compliance assessment, including measuring pulse wave velocity, relating the change in artery diameter to the distending pressure" (p.556). Evidence has shown that the "relationship between endothelial function and aortic pulse wave velocity, is the current ""gold-standard" measure of stiffness, in healthy normotensive individuals'"" (Mc Eniery et al., 2006, p.602).

Blood flow restriction (BFR) training is an "increasingly common practice employed during resistance exercise by athletes attempting to enhance skeletal muscle mass and strength" (Spranger, Krishnan, Levy, O'Leary, and Smith, 2015). The method of applying blood flow restriction involves, "applying a cuff [that] is inflated to a pressure greater than brachial diastolic blood pressure (BP)" (Manini and Clark, 2009, p.78).This technique has also been purported to provide health benefits to the elderly, individuals recovering from joint injuries, and patients undergoing cardiac rehabilitation (Spranger et al., 2015; Karabulut, Abe, Sato, & M.G. Bemben, 2009). Another positive result is that since elderly and recovering athletes cannot withstand high mechanical stress, blood flow restriction can, "provide a unique, beneficial , mode of exercise, even in clinical settings, because it produces positive training adaptations equivalent to the physical activity of daily life" (Loenneke, J.M Wilson , G.J Wilson, Pujol, M.G. Bemben, 2010, p.510). Abe, Kearns, and Sato (2005) stated that "kaatsu [blood flow restriction] training can achieve rapid results" although the mechanisms behind this process are still unknown.

The possibility of an equal or greater increase in arterial compliance may occur when combining BFR to endurance exercise when compared to a higher intensity without BFR. The investigation of the arterial compliance and aerobic capacity to endurance exercise with BFR has yet to be explored. Therefore, this study will investigate the effects of BFR endurance exercise on arterial compliance and changes in electromyography in a short-term training study.

Problem and Purpose Statement

Sufficient research on arterial elasticity and EMG analysis has not been conducted using blood flow restriction during aerobic training on a treadmill in a short-term training study. The purpose of this study was to determine the impact of blood flow restriction on arterial elasticity, EMG activity, and VO_2 max among sedentary and recreationally active males engaged in an 8-week aerobic training program.

Study Purposes

The purposes of this study were to 1) Determine if subjects who were assigned to the blood flow restriction group would have greater EMG activity following training. 2) Determine if subjects who were assigned to the blood flow restriction group would perform better in post-training VO_2 testing than those in the ACSM guideline groups. 3) Determine if blood flow restriction would result in better arterial elasticity and compliance post-training than ACSM guidelines. Furthermore, the purpose of this study was to determine if there were changes in small and large arterial elasticity following the use of BFR cuffs during aerobic exercise when compared to a higher intensity session without BFR. 4) To determine if changes occurred in RHR (resting heart rate), SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), CO (cardiac output), SV (stroke volume), SVR (systemic vascular resistance) and TVI (total vascular impedance) in recreationally active male subjects following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. 5) Determine if there would be greater increases in MVC force following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR.

Significance of the Study

Examining arterial elasticity and compliance, EMG activity, and VO_2 max among sedentary and recreationally active males in a short-term training study will allow for a more thorough profile of cardiovascular and neural muscular adaptations. A 6-week training study will allow time for neuromuscular adaptations to occur as well as changes to the cardiovascular system, such as increased stroke volume and cardiac output, and pulse wave velocity. This study will help provide a better understanding of how blood flow restriction affects the cardiovascular system while performing endurance exercise, and will show comparisons between training with blood flow restriction versus ACSM protocols. The study will further help determine if neuromuscular changes can occur with a shorter aerobic exercise period with blood flow restriction, in comparison with the established guidelines.

Assumptions

1. Participants would adhere to the 6-week training plan.

2. Participants would not participate in additional physical activity after beginning the study.

3. Participants provided accurate information on Health Status Questionnaire.

4. All equipment provided accurate results following proper calibration.

5. All participants performed the VO_2 max test at the best of their ability.

6. All participants arrived 8-hours fasted, hydrated, and rested on pre and post-testing days.

7. All participants would complete the study.

Limitations

1.The study is not representative of the population due to all participants being volunteers and not being randomly sampled.

2. The study was limited to only male participants from a university in South Texas.

3. Health history and medical information were gathered though self-report.

4. Participants were asked to refrain from changes on their current physical activity; however, physical activity performed outside of the study was not monitored.

Delimitations

1. Individuals with signs or symptoms of CVD were not permitted to participate in the study.

2. Individuals younger than 18 and older than 50 were excluded from this study, because of age has on arterial elasticity.

3. Individuals suffering from diseases or disabilities that prevent the individual from undergoing maximal testing were excluded. These included metabolic and cardiovascular diseases, hypertension, joint injuries, and chronic pain.

4. Individuals were required to be 8-hours fasted and adequately hydrated before testing.

Research Questions

In order to test the hypotheses, the following research questions were addressed:

1) Did subjects who were assigned to the blood flow restriction group have greater EMG activity than the low and high group?

2) Did subjects who were assigned to the blood flow restriction group perform better in post-training VO_2 testing than those in the ACSM guideline groups?

3) Did blood flow restriction result in better arterial elasticity and compliance than ACSM guidelines?

4) Did subjects who were assigned to the blood flow restriction group perform better in post-training MVC and Thorstensson testing?

Hypotheses

1) Differences in EMG activity would be found in the blood flow restriction group when compared the other training groups.
2) Subjects in the blood flow restriction group would perform better in post-testing VO_2 testing when compared to the training group that followed ACSM aerobic guidelines.
3) Subjects in the blood flow restriction group would have better arterial elasticity and compliance than the other training groups that followed ACSM aerobic guidelines.
4) Differences on Biodex would be seen in the BFR group when performing MVC and Thorstensson.

Operational Definitions

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

1) **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.
2) **Blood Flow Restriction (BFR):** BFR is a technique that restricts venous blood return during exercise. This process involves cuffs placed over the inguinal crease, to which

they are then inflated to a specific pressure. The cuffs are 5 centimeters wide and contain an inflatable bladder.

3) **Arterial compliance:** the measurement of the elastic properties of the arteries, which has an inverse relationship with arterial stiffness.
4) **Hemodynamics:** Analysis of physical aspects of blood circulation and blood flow.
5) **Pulse Wave Velocity:** Noninvasive assessment of arterial compliance in which velocity of blood pressure wave forms traveling between two different sites are measured.
6) **Biodex:** Is a device used to measure power, force, moment force (torque), and calculating muscle fiber type percentages.
7) **EMG:** Measures neural activity in isolated muscles.
8) **Bod Pod:** Gold standard for measuring body fat and muscle mass using air displacement
9) **Hydration:** Hydration status was deemed adequate when urine specific gravity measured 1.010 and lower as determined by a clinical urine refractometer.

Summary

Research has shown that "arterial stiffness is an independent predictor of mortality and is regulated by a number of factors including vascular smooth muscle tone" (Mc Eniery et al., 2006). While there are ways to reduce this factor by participating in regular aerobic exercise some individuals cannot handle the intensity, such as elderly and rehabilitative patients. Blood flow restriction (BFR) training is an "increasingly common practice employed during resistance exercise by athletes attempting to enhance skeletal muscle mass and strength" (Spranger, Krishnan, Levy, O'Leary, and Smith, 2015). By combining blood flow restriction along with aerobic exercise it is possible that individuals may benefit from the decreased intensity and time, while still receiving positive benefits.

The following research questions investigated the effects of a short term training study, and establish if subjects may have more benefits to neural adaptations, and arterial compliance than from traditional ACSM guidelines. The purposes of this study were to1) Determine if subjects who were assigned to the blood flow restriction group have greater EMG activity. 2) Determine if subjects who were assigned to the blood flow restriction group perform better in post-training VO_2 testing than those in the ACSM guideline groups. 3) Determine if blood flow restriction result in better arterial elasticity and compliance than ACSM guidelines.

Chapter 2 contains a literature review on arterial compliance, the effects of aerobic exercise to arterial compliance, blood flow restriction, and neural adaptations that occur with blood flow restriction. Chapter 3 contains the methodology that occurred in this study. Chapter 4 contains the results and analyses of this study. Chapter 5 includes the conclusion and summary of this study, as well as future recommendations for blood flow restriction training.

CHAPTER II

REVIEW OF THE LITERATURE

The purposes of this study were to 1) Determine if subjects who were assigned to the blood flow restriction group would have greater EMG activity following training. 2) Determine if subjects who were assigned to the blood flow restriction group would perform better in post-training VO_2 testing than those in the ACSM guideline groups. 3) Determine if blood flow restriction would result in better arterial elasticity and compliance post-training than ACSM guidelines. Furthermore, the purpose of this study was to determine if there were changes in small and large arterial elasticity following the use of BFR cuffs during aerobic exercise when compared to a higher intensity session without BFR. 4) To determine if changes occurred in RHR (resting heart rate), SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), CO (cardiac output), SV (stroke volume), SVR (systemic vascular resistance) and TVI (total vascular impedance) in recreationally active male subjects following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. 5) Determine if there would be greater increases in MVC force following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. In this chapter, selected literature about arterial compliance, neural muscular adaptations, and blood flow restriction is reviewed. Included in this review are the following topics (1) arterial compliance, (2) effects of aerobic activity on arterial compliance and neuromuscular adaptations,

(3) blood flow restriction, (4) effects of blood flow restriction on arterial compliance and neuromuscular adaptations.

Arterial Compliance

There are several factors that contribute to cardiovascular disease, however, one of the most important contributors of CVD is arterial stiffness. Several studies over the years have found that, "arterial stiffness is an independent predictor of mortality, and is regulated by a number of factors, including vascular smooth muscle tone" (McEniery et al., 2006, p. 602; Sugawara, Hayashi, Yokoi, Cortez-Cooper, DeVan, Anton, & Tanaka, 2005, p.402). Another study reported similar findings that, "measures of arterial compliance and larger arterial elasticity indices relate to risk factors for coronary artery disease (CAD)" (Fazlioglu et al., 2008). B. Li, Gao, X. Li, Liu, and Wang found that, "elasticity is one of the important characteristics of the arteries and is a direct reflection of the condition of these blood vessels" (2006). Aging brings both structural and functional changes to the arteries, "including fragmentation and degeneration of elastin, increases in collagen, thickening of the arterial wall, and progressive dilation of the arteries" (Sutton-Tyrrell et al., 2004). One noninvasive way to test for arterial stiffness is by using pulse wave velocity (PWV), "PWV is considered to be the most hallowed technique as recently described in the consensus statement on arterial elasticity" (Sugawara et al., 2005). Pulse wave velocity measures the stiffness of an arterial wall, which "provides prognostic information above and beyond that from traditional risk factors" (Cohn, 2006).

In the Rotterdam study researchers found that, "as a consequence of arterial stiffness, systolic blood pressure increases, causing a rise in left ventricular workload, and subsequent hypertrophy…" (Francesco et al., 2005). This particular study consisted of "2835 subjects that participated in the third examination phase" (Francesco et al., 2005). Their data found that, "aortic PWV was found to be a strong and independent predictor or coronary heart disease and stroke" (Francesco et al., 2005). However, one thing that was noted in this study is that the association of PWV and, "coronary heart disease was weak after adjustment for all potential confounders" (Francesco et al., 2005).

In the Framingham heart study Mitchell and colleagues collected data from a total of 2232 participants, and after using multivariable models that, "adjusted for age, sex, systolic blood pressure, use of antihypertensive therapy, total and high density lipoprotein cholesterol concentrations, smoking, and presence of diabetes mellitus, higher aortic PWV was associated with a 48% increase in cardiovascular disease risk" (2009, p. 509). In a similar study which examined pulse wave velocity as a marker of arterial stiffness the Health, Aging, Body Composition (Health ABC) study looked at 2488 participant's aortic PWV. Their data suggests that arterial PWV is, "a marker associated with CHD [coronary heart disease], and CV [cardiovascular] mortality in a well-functioning, community-dwelling population sample" (Sutton-Tyrrell et al., 2004). When subjects were in the 25th percentile of PWV there was a 2-fold increase or greater risk of having CVD. In addition, there was a 2-3 fold increase of a stroke occurring and a 50% increase in CHD event when compared to other individuals who were below this level (Sutton-Tyrrell et al., 2004).

Effects of Aerobic Activity on Arterial Compliance and Neuromuscular Adaptations

It has been previously stated that arterial stiffness is a contributing factor for cardiovascular risk. While conversely, “exercise training appears to be associated with reduced arterial stiffness or increased compliance in healthy humans” (Cameron & Dart, 1994). Additionally, when the effects of advancing age are controlled for, arterial stiffness is less in persons with higher maximal oxygen consumption” (Edwards, Schofield, Magyari, Nichols, & Braith, 2003). Other benefits from exercise include a healthier body weight, which is, “associated with low aerobic capacity and impaired endothelial function, of which both serve as a strong and independent risk factors of mortality from cardiovascular and metabolic disease” (Schjerve et al., 2008). Furthermore, “exercise training-induced alterations in arterial stiffness would be of great benefit in CAD, potentially reducing myocardial oxygen demand and symptoms of ischemia” (Edwards et al., 2003).

The study conducted by Edwards and colleagues, consisted of a total of 20 patients who had been diagnosed with CAD. Subjects were either assigned to a 12 week standard cardiac rehabilitation program or a 12 week control. After the 12 week study results should that subjects who participated in the endurance program had, “a reduction in arterial stiffness as evidenced by a reduction in augmentation index (30% at baseline *v* 26% at 12 weeks) and an increase in the travel time of the reflected wave” (Edwards, et. al., 2004). The current study suggests that, “in patients with CAD, endurance exercise training improves systemic arterial stiffness…exercise training may result in a decrease in myocardial oxygen demand and ischemic symptoms” (Edwards, et. al., 2004, p. 542).

In the study by Schjerve and colleagues in 2008, they examined how aerobic endurance can improve cardiovascular health in obese adults. A total of 40 subjects were randomized into strength training, moderate intensity aerobic training, or high intensity aerobic interval training program for a total of 12 weeks. Their results showed that, “both aerobic exercise training at either high or moderate intensities and high-intensity strength training improve endothelial function and decrease the cardiovascular risk profile in obese adults” (Schjerve et al., 2008). It was shown though that high intensity aerobic interval training that the greatest improvement in endothelial function. Along with improvement in endothelial function participants also had an increase in VO_2 max. The interpretations of this study show, “that it might be possible to reverse impaired endothelial function, decrease cardiovascular risk and improve exercise capacity in subjects that have difficulty performing whole-body aerobic training” (Schjerve et al., 2008).

Along with changes to the cardiovascular system from aerobic training, neuromuscular changes also occur. In 2001, Allen and colleagues noted, “increases in muscular activity, such as those occurring during endurance exercise, are associated with rapid and dramatic adaptations of the cardiovascular and musculoskeletal system”. Similarly reported in another study, “regular endurance training induces numerous physiological adaptations that facilitate improved exercise capacity…” (Gibala et al., 2006, p.901).

Blood Flow Restriction

Blood flow restriction was popularized in Japan over 40 years ago, and since then has been used widely for rehabilitation purposes, since it allows an individual to train at a lower intensity while still gaining the benefits of training at higher loads There are different formulas for inflating blood flow restriction cuffs, but “typically the cuff is inflated to a pressure greater than brachial diastolic blood pressure (BP) and upward of pressures exceeding systolic BP” (Manini & Clark, 2009). Blood flow restriction to the extremities, “occludes venous return and causes arterial blood flow to become turbulent and a reduction in blood velocity is seen distal of the cuff" (Manini & Clark, 2009). Interestingly, "numerous studies using low intensity exercise combined with blood flow restriction (LI-BFR) have shown muscle hypertrophy to occur with a training intensity as low as 20%" (Loenneke, Wilson, Marin, Zourdos, &Bemben, 2011). Another study has also shown that, "blood flow restriction cuffs has been shown to mimic the hypertrophic response of a 70% 1RM exercise when using 20% 1RM" (Park, Kwak, Harveson, Weavil, & Seo, 2015). However, "the mechanisms underlying the hypertrophic response observed with BFR exercise training are not known, although they are likely to rise from a systemic and/or local response pathway" (Manini & Clark, 2009).

One important aspect of blood flow restriction is that it allows for adaptations to occur at a lower intensity, which is beneficial to "many individuals such as the elderly and rehabilitating athletes [who] are unable to withstand the high mechanical stresses placed upon the joints during heavy resistance training" (Loenneke, J. Wilson, G. Wilson, Pujol, Bemeben, 2010). Furthermore, Loenneke and colleagues stated that, "this style of training can provide a unique, beneficial mode of exercise, even in clinical settings, because it produces positive training adaptations equivalent to the physical activity of daily life (10-30% of maximal work capacity)" (2010).

Although, adequate research has been conducted using blood flow restriction some safety concerns remain, "obvious potential safety concerns for practitioners with respect to blood flow changes post-exercise (PObf)" is probably the most examined cardiovascular change while using blood flow restriction (Loenneke et al., 2010). Research regarding PWV is limited and contradicting, a study conducted by Collier et al. (2008) "found that 4 weeks of resistance training (65% 1 RM) increased peripheral PWV". However, several other studies have shown that there are no harmful effects to arterial stiffness from blood flow resistance training. (Cortez-Cooper et. al., 2005; Casey et al., 2007; Yoshizawa et al., 2009).

While there has been extensive research of the effects of blood flow restriction, while performing resistance training there are very limited studies that have examined the long term effects of blood flow restriction, in combination with aerobic endurance training. Although several walk-training studies have been conducted there is not a substantial review of those studies.

Effects of Blood Flow Restriction on Arterial Compliance and Neuromuscular Adaptions

Because of the mechanisms behind blood flow restriction many studies have looked at the effects on arterial compliance following a training session with blood flow restriction. Fahs and colleagues cited that, "concerns have been raised about its impact on the cardiovascular system; both acute and chronic" (2010). However, most the research has been focused on resistance training with blood flow restriction because, "some studies have shown that acute and chronic resistance exercise may increase arterial stiffness (decrease compliance)…" (Fahs et al., 2010, p. 2969). Furthermore, a study conducted by Credeur et al., 2009 stated that, "blood flow restricted (BFR) exercise has been shown to reduce endothelial function". Reduction in endothelial function is a major contributor to reduced arterial compliance and increased arterial stiffness.

The study conducted by Fahs and associates looked at different types of resistance exercises and the effects on arterial compliance and calf blood flow. The study involved a total of 11 recreationally active men between the ages of 18 and 35 years old. They participated either in high intensity, low intensity, or low intensity with blood flow restriction, and completed three acute resistance exercise sessions. The findings of the study state that, “both traditional HI [high intensity] as well as LI [low intensity] and LI-BFR [low intensity-blood flow restriction] resistance exercise cause similar post-exercise increases in systemic large artery compliance.” (Fahs et al., 2010). However, the high intensity exercise group was the only one that had increased CVC (calf vascular conductance). It was stated that, “LI-BFR exercise also did not increase post-exercise calf blood flow, likely due to reductions in flow mediated vasodilation” (Fahs et al., 2010).

A study conducted by Ozaki, Miyachi, Nakajima, and Abe, examined the effects of a ten week walk training program with blood flow restriction on carotid arterial compliance, as well as muscle size. They had a total of 23 sedentary elderly men and women participate in their study and were randomized into a control walk group or a blood flow restriction walk group. Interestingly, Ozaki and colleagues found that both, “strength and thigh muscle size increased following 10 weeks of walk training combined with BFR…in addition, carotid arterial compliance improved by BFR walk training” (2010, p.3). This suggest along with other research that, “concurrent improvements in arterial compliance and muscle hypertrophy can be achieved with walk training with BFR” (Ozaki et al., 2010). Another well researched area in blood flow restriction are the muscular adaptations that occur from blood flow restriction training. Evidence has shown that there is an application in clinical settings for elderly patients and recovering athletes who cannot train at high intensities. While many studies have looked at the effects of resistance training, this section will focus on the effects of aerobic exercise in combination with blood flow restriction.

The study conducted by Takashi Abe and colleagues wanted to examine if muscle size and strength would increase following walk training with restricted venous blood flow from the leg muscle while using Kaatsu (blood flow restriction cuffs) during walk training. This included 18 healthy men who were randomized into groups walking with or without Kaatsu for 3 weeks at 50 m/min. Researchers found that, "3-weeks of twice-daily Kaatsu-walk training increased thigh muscle CSA [cross sectional area] and volume in young men ($P < 0.01$)" (Abe, et. al., 2005). When results were analyzed for 1-RM "leg press and leg curl 1-RM strength increased by 7.4 and 8.3%, respectively, in the Kaatsu-walk group after 3 weeks of training ($P <0.05$)" (Abe, et. al., 2006). Other important finding were that, "a single bout of Kaatsu-walk exercise significantly increased serum GH concentrations, even though the training intensity was very low (50m/min) ($P < 0.01$)" (Abe, et. al., 2005).

In another study examining walk training with blood flow restriction. Abe and colleagues instead looked at effects on muscle strength and aerobic capacity in older adults. They stated that, "slow walk training combined with restricted leg muscle blood flow (KAATSU) produces muscle hypertrophy and strength gain in young men" (Abe, et. al., 2005). Applying this to the elderly population would be advantageous because the intensity and duration would be lower in comparison to following the recommended training protocol from ACSM, which would be, "approximately 60 minutes, a total training time of approximately 5 to 8 hours a week" (Abe, et. al., 2010). The conclusion of this particular study showed that, "6 weeks of KAATSU walk training can produce increases in muscle strength and size as well as functional ability of aging adult participants" (Abe, et. al., 2010). However, when it came to aerobic capacity no significant changes occurred over the 6 week period.

Conclusion

In conclusion, the literature presented showed sufficient research on arterial compliance in response to aerobic exercise. However, there was not an adequate amount of research when pertaining to aerobic exercise and neuromuscular adaptations, particularly when performing walking and running. Arterial compliance in relation to blood flow restriction, when combined with aerobic exercise, is another area that had insufficient information. Nevertheless, research in muscular adaptations with blood flow restriction was abundant when in combination with resistance training. More research needs to be done to examine the effects of blood flow restriction when performing aerobic exercise such as running, and how it will effect arterial compliance and neuromuscular adaptations.

CHAPTER III

METHODS

The purposes of this study were to 1) Determine if subjects who were assigned to the blood flow restriction group would have greater EMG activity following training. 2) Determine if subjects who were assigned to the blood flow restriction group would perform better in post-training VO_2 testing than those in the ACSM guideline groups. 3) Determine if blood flow restriction would result in better arterial elasticity and compliance post-training than ACSM guidelines. Furthermore, the purpose of this study was to determine if there were changes in small and large arterial elasticity following the use of BFR cuffs during aerobic exercise when compared to a higher intensity session without BFR. 4) To determine if changes occurred in RHR (resting heart rate), SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), CO (cardiac output), SV (stroke volume), SVR (systemic vascular resistance) and TVI (total vascular impedance) in recreationally active male subjects following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. 5) Determine if there would be greater increases in MVC force following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. In this chapter, the methods and procedures used in the course of this study are presented and discussed.

Participants

The University of Texas Rio Grande Valley Institutional Review Board approved the study procedure for Human Subjects, and all subjects read and signed an informed consent. A total of 44 recreationally active males between the ages of 18-50 participated in this short-term training study. Of this group a total of 41 participants completed the pre and post-testing, as well as 90% of the training. Subjects were recruited from the University of Texas Rio Grande Valley, and consisted of undergraduate and graduate male students, and others who were interested in participating in our study. Recruitment was completed through classroom recruitment, as well as an in-person script. Participants were also recruited by means of fliers and word of mouth at UTRGV. Participation in this study was voluntary and subjects were allowed to withdraw at any time.

Inclusion Criteria

1. Participants who were within the 18 to 50 year age range.

2. Participants who had no medical history of hypertension, cardiovascular disease, respiratory disease, joint or muscle problems, any metabolic disease, chronic pain, or currently ingesting medication that might interfere with vascular function.

Exclusion Criteria

1. Participants ingesting medication for hypertension, cardiovascular disease, or chronic pain.

2. Participants ingesting medication that may interfere with vascular function.

3. Participants who had joint or muscle problems.

4. Participants whom had a medical history of hypertension, cardiovascular disease, respiratory disease, joint or muscle problems, or any metabolic disease.

5. Participants who were suffering from chronic back pain and joint injuries in the lower back extremities.

Recruitment

Participants were recruited from The University of Texas Rio Grande Valley through classroom recruitment; in which a professor permission script was used as a well as an in-person script (see appendix for forms). Participants were also recruited by means of fliers and word of mouth at UTRGV (see appendix for flier). Participation in this study was voluntary and participants were allowed to withdraw at any time.

Experimental Protocol

All study procedures were conducted in the Exercise Science Laboratory (M-1 building, room 216). Time schedules were agreed on by the subject and researcher to when it is most convenient to the subject to be both fasted (for at least 8 hours) and hydrated, for pre and post-testing. Hydration was monitored with the use of a Clinical Urine refractometer 300005 (SPER Scientific, Scottsdale, AZ, USA), that will require a subject to provide a urine sample to determine the level of current hydration (hydration is at or below 1.010). This study was a total of 8 weeks long with weeks 1 and 8 consisting of pre and post-testing and weeks 2- 7 consisting of actual training. Any sessions prior to the beginning of week 2 will be introductory in nature, including initial paperwork and recording necessary values prior to training.

On the first day, the participants filled out questionnaires and were familiarized with the study procedures before starting the exercise sessions. Participants that answered yes to any PAR-Q question, or have blood pressure at or higher than 140/90 mmHg were excluded from this study. Following initial screening (PAR-Q and health questionnaire, a copy of both forms will be provided) and familiarization, anthropometric measurements included resting heart rate, blood pressure, height, weight, body composition, and thigh circumference. Weight and body fat percentage will be measured using the BodPod (gold standard body composition based on air displacement). Thigh circumference was taken at the mid-point of the greater trochanter and lateral epicondyle. Inflation of the blood flow restriction cuffs was based on capillary refilling time. Participants will also perform their VO_2 max using Bruce Protocol day one will last for a total of 1.5 hours.

The second day consisted of collecting measurements using SphygmoCor® CPV Pulse Wave Analyzer (AtCor Medical, Itasca, IL, USA), HDI/Pulse Wave CR-2000 TM Research Cardio Vascular Profiling System (Hypertension Diagnostic, Inc., Eagan, Minnesota, USA). BodPod 2000A (Life Measurement, Inc., CA, USA), and Biodex (Biodex Medical Systems, Inc., NY, USA) in conjunction with EMG Delysys ® Trigno ™ Wireless System (DELSYS Inc., Boston, MA, USA). These sessions averaged for a total of 2 hours. When performing measurements using SphygmoCor the subjects lied down in the supine position for a minimum of 10 minutes and baseline arterial elasticity and hemodynamics were measured using Hypertension diagnostic (noninvasive equipment conducts measurements of arterial stiffness via placing a sensor on the radial artery at the right wrist and a cuff to the left arm to measure blood pressure) and measurement of pulse wave velocity using SphygmoCor (which was conducted noninvasively using a pulse wave velocity analyzer in segmental measures at the carotid, femoral, and the dorsalis pedis while wearing three electrodes on the chest to monitor the heart's electrical activity). EMG electrodes were placed on subject's right quadriceps. Measurements to find the belly of the rectus femoris, vastus lateralis and vastus medialis were done by having a subjects lie down and raising their torso to a 45˚ angle and raising their legs with an 8 inch foam roller placed under their knees. Measurements were found by locating the subject's iliac crest and the top of the patella (rectus femoris, lateral side of patella (vastus lateralis) and joint space of patella (vastus medialis) for the respective muscles. Once the distance was found between the iliac crest and other sites a calculation was used to determine where the electrodes would be place. For the rectus femoris 50% of the total distance was where the electrode would be placed, 80% of the total distance was where the electrode would be placed for the vastus lateralis and 1/3rd of the total distance was where the electrode would be placed for the vastus medialis.

Weeks 2-7 will include the actual training sessions in which each participant will come in and perform the specified routine on the treadmill 3 times a week with at least one day of rest between sessions. Upon finishing the 6-week training program, week 8 will consist of measuring all variables that were recorded in week 1. For pre and post-testing recordings subjects will be required to be fasted and hydrated prior to testing. Once body anthropometric and body composition measurements have been taken, the subject will perform their VO_2 max using Bruce Protocol (Bruce, Kusumi, & Hosmer, 1973) during their first week and last week. Heart rate (via Polar chest strap and watch) will be monitored continuously while performing VO_2 max testing. This first session lasted about 35 minutes.

This study will consist of 4 different groups: A control group that will only come to the lab for pre and post-testing and perform the normal daily routine weeks 2-7. The high intensity training group will train at 60-80% of their VO_2 reserve for 30 minutes 3 times a week. The low intensity training group will train 30-45% of their VO_2 reserve for 30 minutes 3 times a week. The low intensity BFR training group will train at 30-45% of their VO_2 reserve for 30 minutes 3 times a week. The time training will be a total of 9 hours for the 6 weeks of training except for the control group who will only come in for pre and post-testing. Week 8 will consist of measuring all variables that were recorded in week 1 as outlined above and will take the same amount of time.

Minimal Risk: The minimal risk includes discomfort using blood flow restriction cuff (for the 30-minute run/walk sessions) and performing the VO_2 max test (the subject may feel tired right after the test and feel sore a day after the test). They will be screened in detail before being allowed to participate. If at any time they are unable to complete any task they will be allowed to stop.

The research team is required to calibrate all the equipment (which will be performed regularly according to instructions provided by the manufacture), know how to properly use the equipment, and have all documentation done to conduct research. The research team will conduct measurements on the subject of the same gender.

Moxus VO_2 Metabolic Cart

Participants were required to wear a breathing mask that was connected to the MOXUS Modular VO_2 System (AEI Technologies, Inc., Pittsburgh, PA, USA) through mask and breathing tubes. The metabolic cart computer collected inspired oxygen and expired carbon dioxide and the software recorded analysis and calculations of energy expenditure and oxygen consumption. Heart Rate was assessed continuously by wearing a Polar Heart Rate Monitor FT7 series (Polar Electro Inc., Lake Success, NY, USA).

Bruce Protocol

The Bruce Protocol (Bruce, Kusumi, & Hosmer, 1973) consisted of multiple stages of increasing speeds and inclines until maximal exertion was reached. The metabolic cart (MOXUS

Modular VO_2 System) continuously recorded oxygen consumption and carbon dioxide production during the test.

Table 1. Bruce Protocol

Stage	Minutes	% Grade	Km/Hr	MPH
1	3	10	2.7	1.7
2	6	12	4	2.5
3	9	14	5.4	3.4
4	12	16	6.7	4.2
5	15	18	8	5
6	18	20	8.8	5.5
7	21	22	9.6	6

Clinical Urine Refractometer

Participants are required to provide a urine sample at the beginning of each session. Hydration was be measured by using 1-3 drops of the urine sample on to the lens of the urine refractometer (Refractometer 300005; SPER Scientific, Scottsdale, AZ, USA). The device was then pointed at a light source and the level of refraction, caused by the sample, was recorded. The device was then cleaned and the rest of the urine was discarded into the biohazard waste bin.

HDL/PulseWave CR-2000TM Research Cardio Vascular Profiling System

Participants were instructed to lie in the supine position with their arms held comfortably abducted from their bodies by roughly 15 degrees and legs separated comfortably, have an appropriate-sized blood pressure cuff placed above the left antecubital space, and a plastic wrist stabilizer on the right wrist to minimize movement while the measurements were taken place. The pulse wave analysis sensor was placed proximal to the crease between the wrist and hand with the sensor lined over the radial artery at a point of a strong pulse. The sensor was adjusted to signal strength of 18-22 before each recording. When recording, the subject would be required to stay as still as possible for duration of about a minute, in which blood pressure would be taken before a 30 s time recording took place. The device measured blood pressure, heart rate, stroke volume, left ventricular ejection time, systemic vascular resistance, total vascular impedance, and small and large arterial elasticity.

Pulse Wave Velocity

Analysis of pulse wave velocity was conducted noninvasively using a pulse wave velocity analyzer; SphygmoCor® Pulse Wave Analyzer (AtCor Medical Pty. Ltd., Sydney Australia). Subject required three electrodes to be attached to monitor the heart's electrical activity, which were placed at the top and bottom of the sternum and at the bottom of the rib cage near the mid-axillary line. The subject lied down and had segmental measures take at the carotid (neck), radial (wrist), femoral artery (groin), and the posterior tibial (foot). Measurements were taken to determine the time that it takes to propagate a pulse from one site to another; which used four sites to acquire 3 different measurements: carotid to radial (upper peripheral), carotid to femoral (central), and femoral to posterior tibial (lower peripheral).

BodPod

BodPod 2000A (Life Measurement, Inc., CA, USA), is the gold standard for measuring body composition based on air displacement. The subjects were required to take off unnecessary clothing, jewelry, shoes, and socks before entering the BodPod and then placed a swim cap on their head to ensure that the subject's hair did not interfere with air displacement.

Delsys Electromyography

EMG Delysys ® Trigno ™ Wireless System (DELSYS Inc., Boston, MA, USA), wireless system was used on subjects when they performed leg extensions on the Biodex. Electrodes were placed on their vastus lateralis, rectus femoris, and vastus medialis. The area were the electrodes were placed was shaved and wiped down with alcohol to ensure proper adhesion.

Biodex

Biodex (Biodex Medical Systems, Inc., NY, USA), is a multi-joint system that was used to test subjects' isometric and isokinetic right leg extension. This device is used to measure power, force, and moment force (torque).

BFR (blood flow restriction) Cuff

The elastic cuffs are 50 mm in width and were filled with air to create pressure to restrict blood flow. The cuffs are to be connected to an electronic air pressure control system that monitors the restrictive pressures. Thigh circumference was taken at the mid-point of the greater trochanter and at the lateral epicondyle. The cuffs were then inflated to reach an individual's final pressure depending on thigh circumference: <45–50 cm = 120 mmHg; 51–55 cm = 150 mmHg; 56–59 cm = 180 mmHg; and ≥60 cm = 210 mmHg. The BFR cuffs were placed on the uppermost portion of the thigh and tightened to the initial pressure. The cuffs were tightened to an initial pressure rage of 50-55 mmHg for males and 55-60 mmHg for females on the 20-minute walk/run at 40% VO_2 intensity with the BFR cuffs inflated and 40-45 mmHg for both sexes on the 20-minute walk/run at 40% VO_2 intensity without the BFR cuffs inflated. Inflation began at 120 mmHg and was slowly inflated to a maximal inflation. The pressure was slowly increased, by 20 mmHg, by holding the pressure for 30 s and releasing for 10 s between increments until maximal inflation was reached.

Statistical Analysis

Analysis of covariance (ANCOVA) and 2-way analysis of variance (ANOVA) with repeated measures was used to see if significant differences exist in large and small arterial elasticity, central and peripheral pulse wave velocity, blood oxygen level, heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, and total vascular impedance, EMG activity, MVC and Thorstensson. Using Pearson Correlation Coefficient, the relationships between the variables was assessed. An alpha of 0.05 was used to determine statistical significance and data were analyzed using SPSS 23.0 for Windows (IBM Corporation, New York, USA).

CHAPTER IV

RESULTS

The purposes of this study were to 1) Determine if subjects who were assigned to the blood flow restriction group would have greater EMG activity following training. 2) Determine if subjects who were assigned to the blood flow restriction group would perform better in post-training VO_2 testing than those in the ACSM guideline groups. 3) Determine if blood flow restriction would result in better arterial elasticity and compliance post-training than ACSM guidelines. Furthermore, the purpose of this study was to determine if there were changes in small and large arterial elasticity following the use of BFR cuffs during aerobic exercise when compared to a higher intensity session without BFR. 4) To determine if changes occurred in RHR (resting heart rate), SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), CO (cardiac output), SV (stroke volume), SVR (systemic vascular resistance) and TVI (total vascular impedance) in recreationally active male subjects following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. 5) Determine if there would be greater increases in MVC force following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. In this chapter, the methods and procedures used in the course of this study are presented and discussed.

Subject Characteristics

Forty-four male participants were recruited for the study and forty-one completed the study. Table 1 shows descriptive statistics that were taken from the study population. Participants were recruited from the University of Texas Rio Grande Valley at the Brownsville campus.

Table 2. Pre-Testing Descriptive Statistics

Variables	Blood Flow (n=10)	Low Intensity (n=8)	High Intensity (n=11)	Control (n=10)
Age (yr)	24.6 (±4.9)	23.0 (±4.0)	25.9 (±8.3)	24.8 (±6.5)
Height (cm)	173.2 (±8.0)	172.6 (±6.9)	173.8 (±5.5)	176.8 (±6.3)
Weight (kg)	82.0 (±13.6)	86.4 (±30.7)	93.1 (±26.8)	87.9 (±17.1)
Body Fat Percentage (%)	23.5 (±7.1)	25.1 (±12.9)	26.8 (±8.7)	24.1 (± 8.4)
VO_{2MAX} (ml/kg/min)	40.9 (±8.2)	41.4 (±6.6)	39.6 (±8.4)	42.8 (± 6.4)

Values are reported as means (SD).

Table 3. Post-Testing Descriptive Statistics

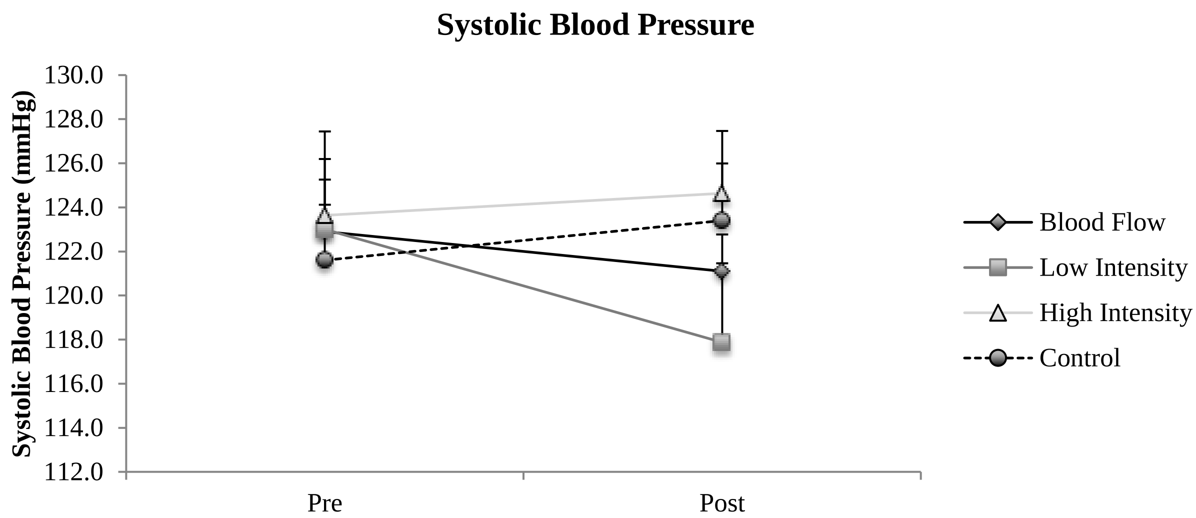
Variables	Blood Flow (n=10)	Low Intensity (n=8)	High Intensity (n=11)	Control (n=10)
Weight (kg)	83.3 (±14.7)	86.3 (±30.4)	93.1 (±25.9)	87.4 (±16.4)
Body Fat Percentage (%)	24.3 (±8.7)	27.6 (±11.2)	26.0 (±10.5)	24.7 (±9.3)
VO_{2MAX} (ml/kg/min)	43.9 (±7.6)	43.1 (±7.4)	42.0 (±10.0)	43.4 (±7.0)

Values are reported as means (SD).

Hemodynamic Responses

Figure 1 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on systolic blood pressure (SBP) in males. All groups were statistically similar ($p>.05$) for all effects and interactions and were reported together.

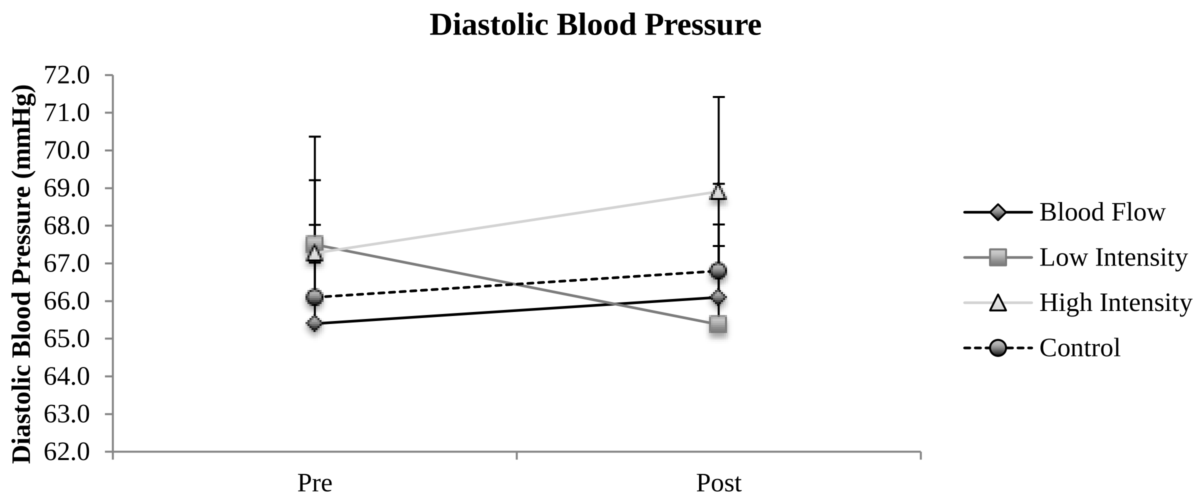
Figure 1. Systolic Blood Pressure



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 2 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on diastolic blood pressure (DBP) in males. All groups were statistically similar (p>.05) for all effects and interactions and were reported together

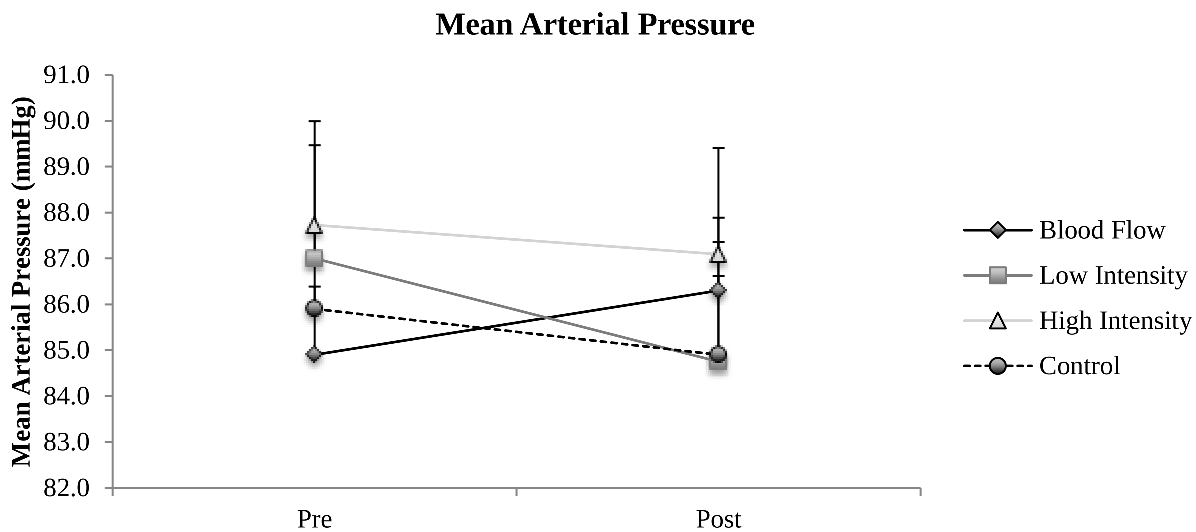
Figure 2. Diastolic Blood Pressure



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 3 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on mean arterial pressure (MAP) in males. All groups were statistically similar (p>.05) for all effects and interactions and were reported together

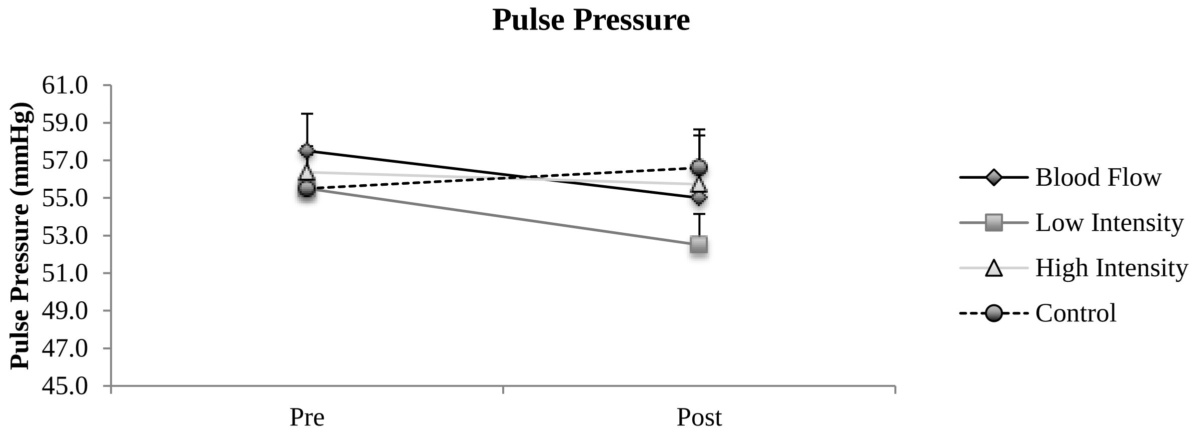
Figure 3. Mean Arterial Pressure



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 4 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on pulse pressure (PP) in males. All groups were statistically similar (p>.05) for all effects and interactions and were reported together

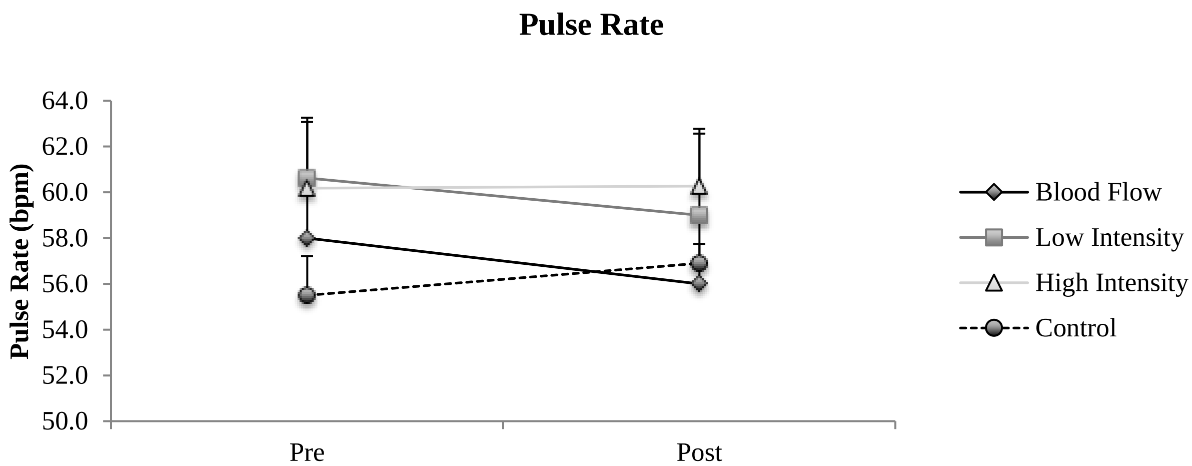
Figure 4. Pulse Pressure



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 5 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on pulse rate (PR) in males. All groups were statistically similar ($p>.05$) for all effects and interactions and were reported together.

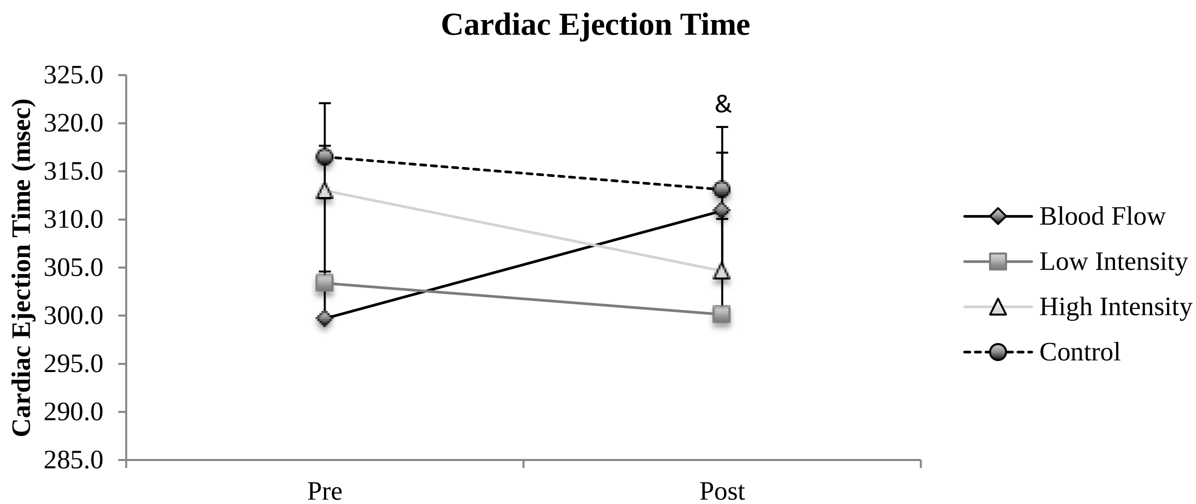
Figure 5. Pulse Rate



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

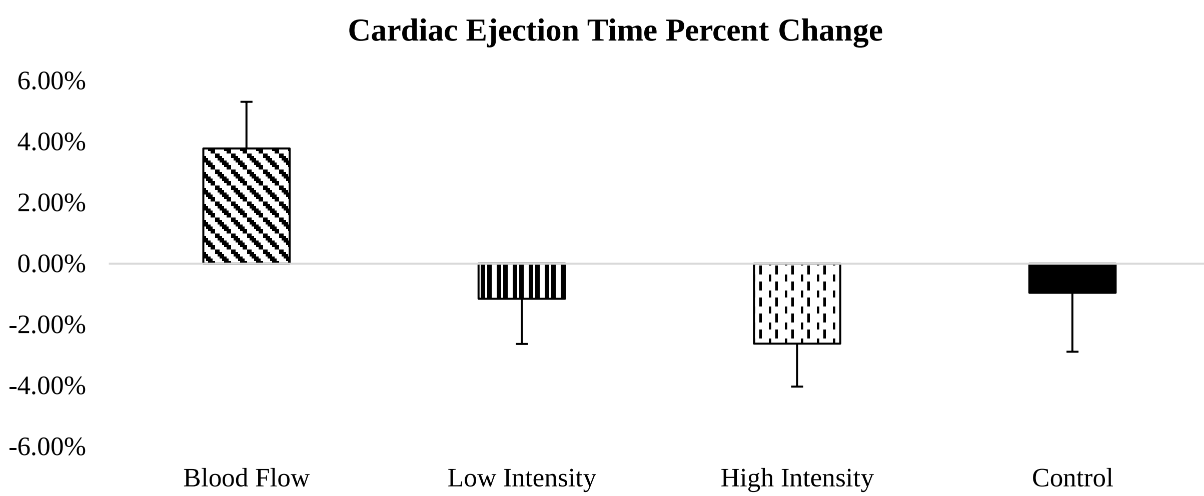
Figures 6 and 7 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on cardiac ejection time (CET) in males. Repeated measures ANOVA found significant interactions between time and group ($p<.05$). All other groups were statistically similar ($p>.05$) for all effects and interactions and were reported together.

Figure 6. Cardiac Ejection Time



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). [&] Represents significant time and group interaction (p<.05). Values reported as mean ±SE.

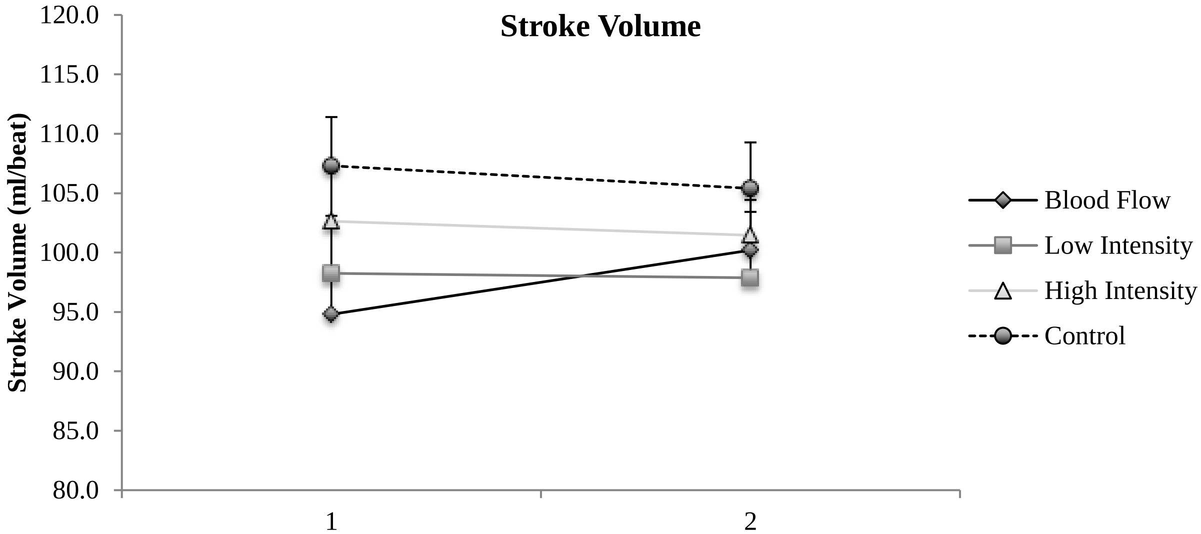
Figure 7. Cardiac Ejection Time Percent Change



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 8 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on stroke volume (SV) in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

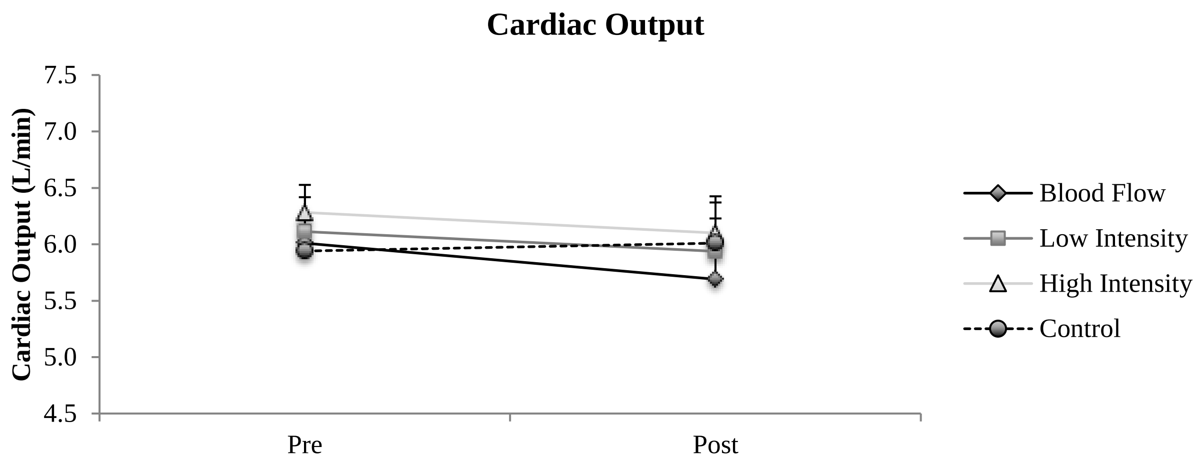
Figure 8. Stroke Volume



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 9 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on cardiac output (CO) in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

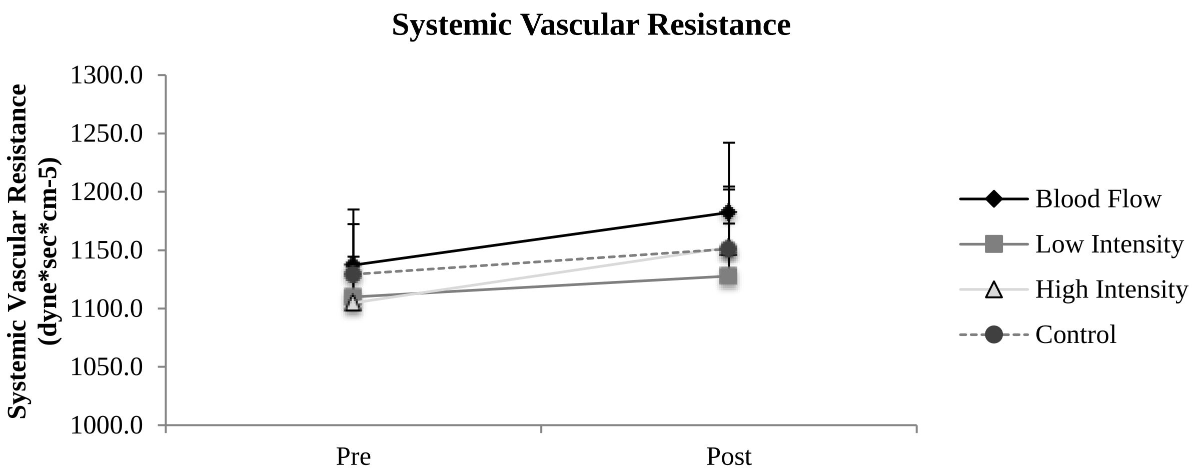
Figure 9. Cardiac Output



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 10 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on systemic vascular resistance (SVI) in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

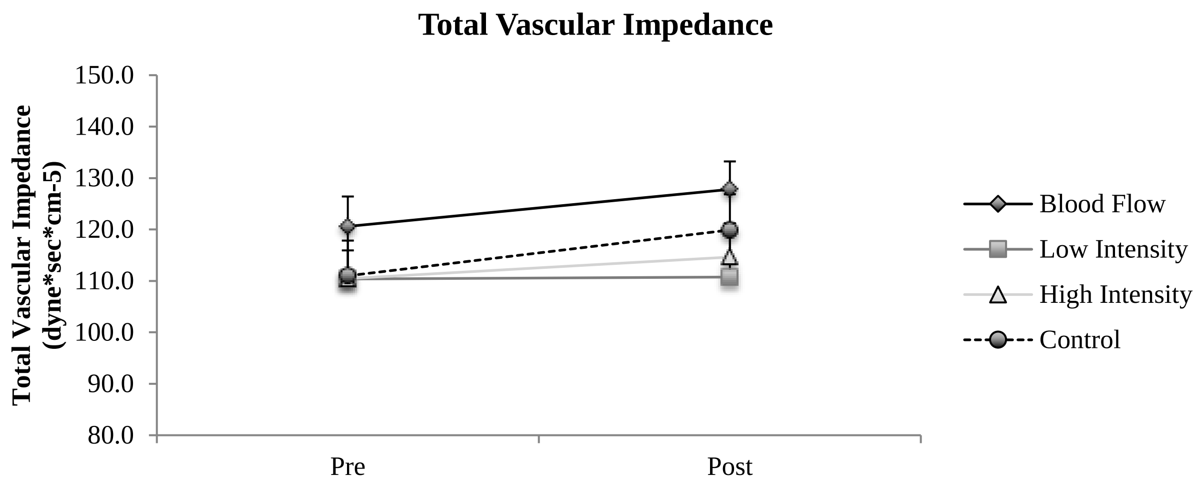
Figure 10. Systemic Vascular Resistance



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 11 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on total vascular impedance (TVI) in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

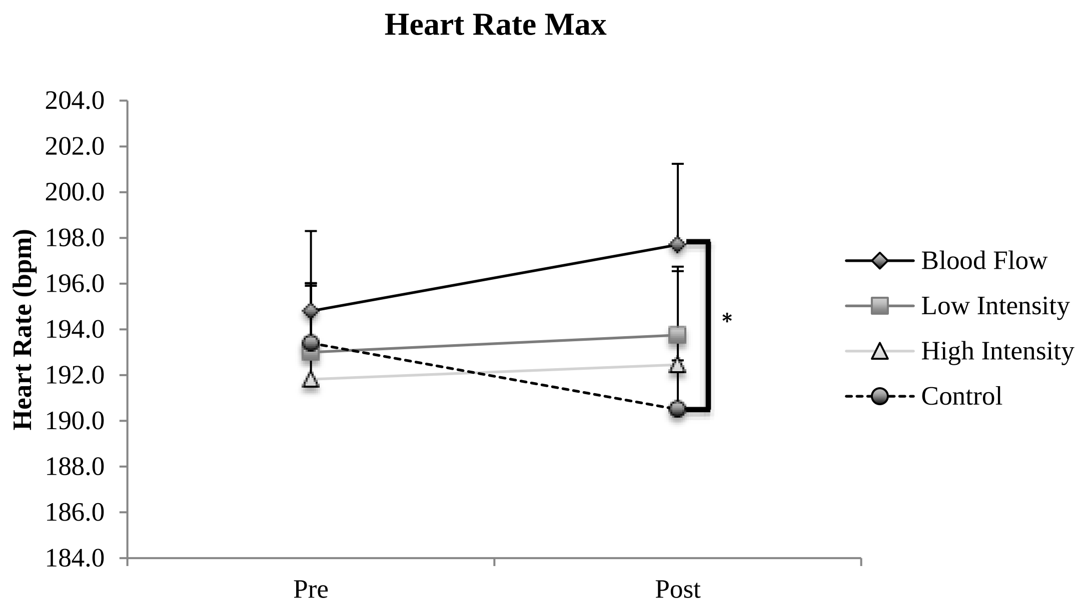
Figure 11. Total Vascular Impedance



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

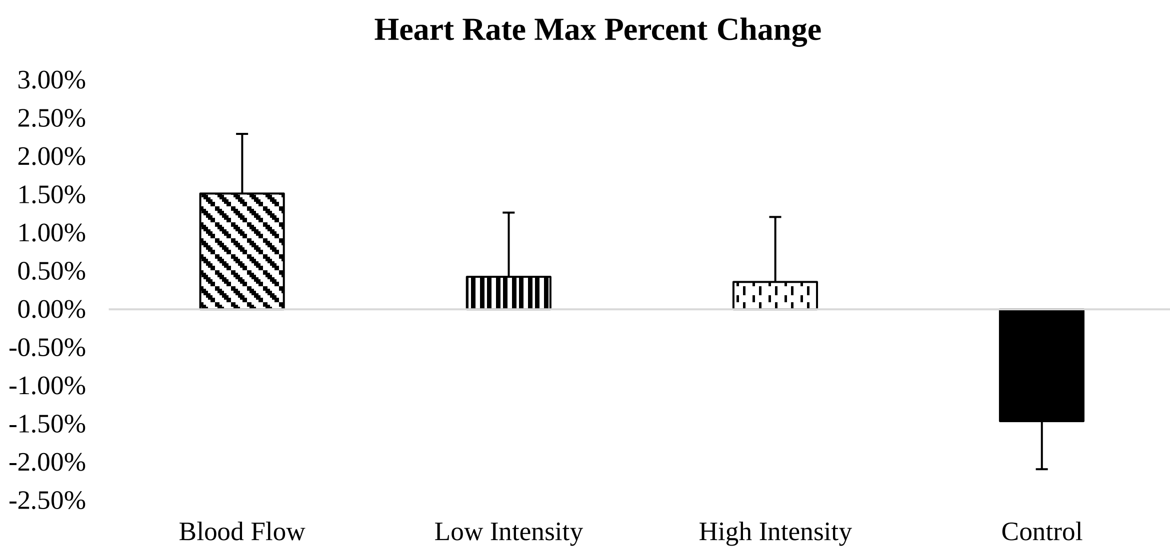
Figures 12 and 13 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on heart rate (HR) in males. ANCOVA showed significance of (p=.05) post-hoc analysis showed significance (p<.05). Significance was found between BFR group and control group with BFR having a higher post-training maximum heart rate. All other categories were statistically similar (p>.05) for all effects and interactions and were reported together.

Figure 12. Heart Rate Max



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). * Represents significant condition difference between BFR and control (p=.05).Values reported as mean ±SE.

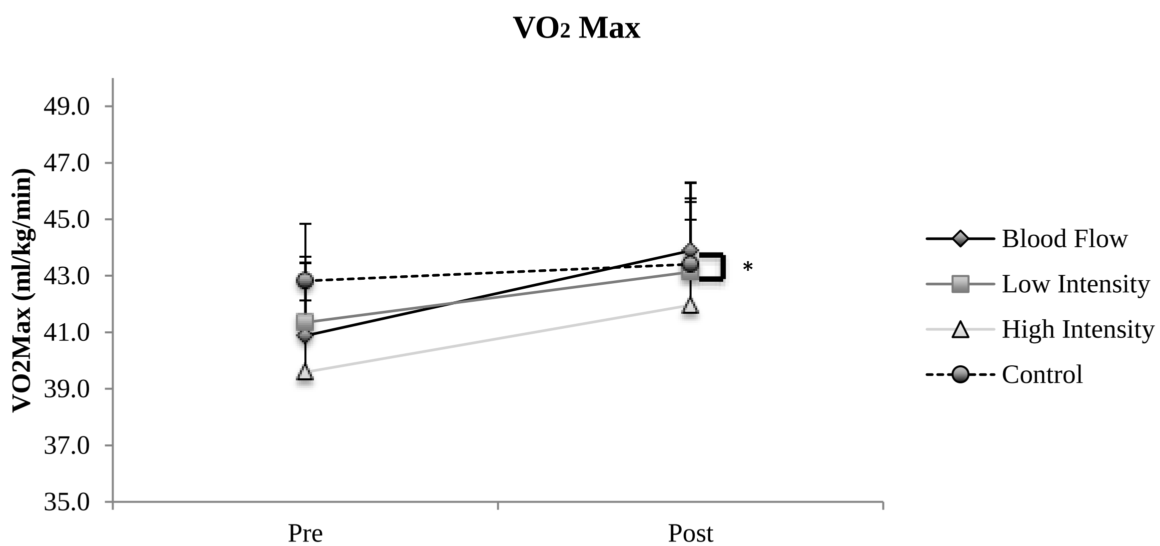
Figure 13. Heart Rate Max Percent Change



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

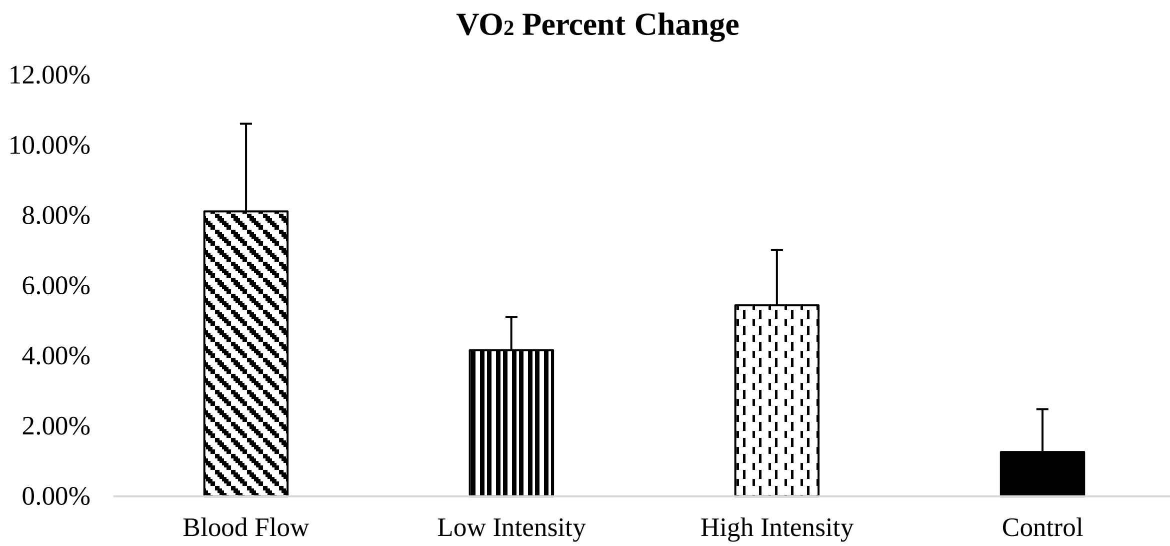
Figures 14 and 15 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on VO_2 Max in males. ANCOVA showed significance group differences (p<.05) and post-hoc analysis revealed a significance of (p<.05) between BFR group and control group with BFR having a higher post-training VO_2. Partial eta showed that 21% of the total variability in VO_2 value was explained by the independent variable (training protocol). All other categories were statistically similar (p>.05) for all effects and interactions and were reported together.

Figure 14. VO_2 Max



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). * Represents significant condition difference between BFR and control (p<.05).Values reported as mean ±SE.

Figure 15. VO_2 Max Percent Change

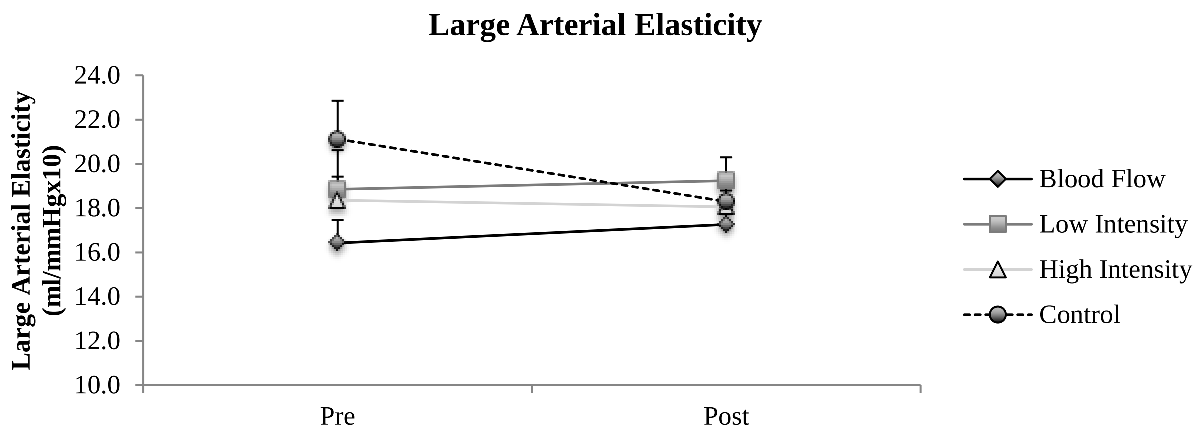


Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Arterial Compliance

Figure 16 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on large arterial elasticity (LAE) in males. All categories were statistically similar ($p>.05$) for all effects and interactions and were reported together.

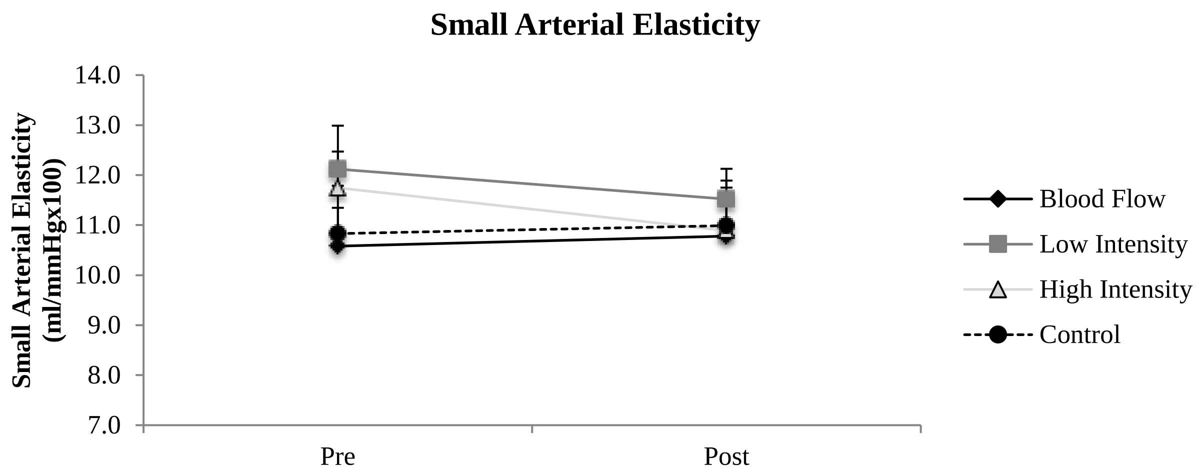
Figure 16. Large Arterial Elasticity



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 17 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on small arterial elasticity (SAE) in males. All categories were statistically similar ($p>.05$) for all effects and interactions and were reported together.

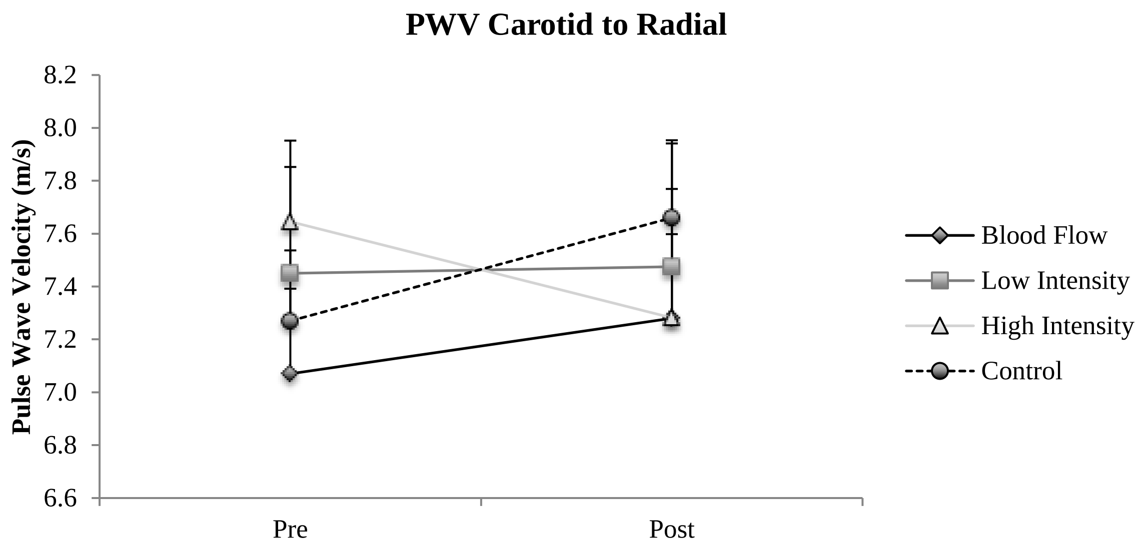
Figure 17. Small Arterial Elasticity



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 18 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on PWV Carotid to Radial in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

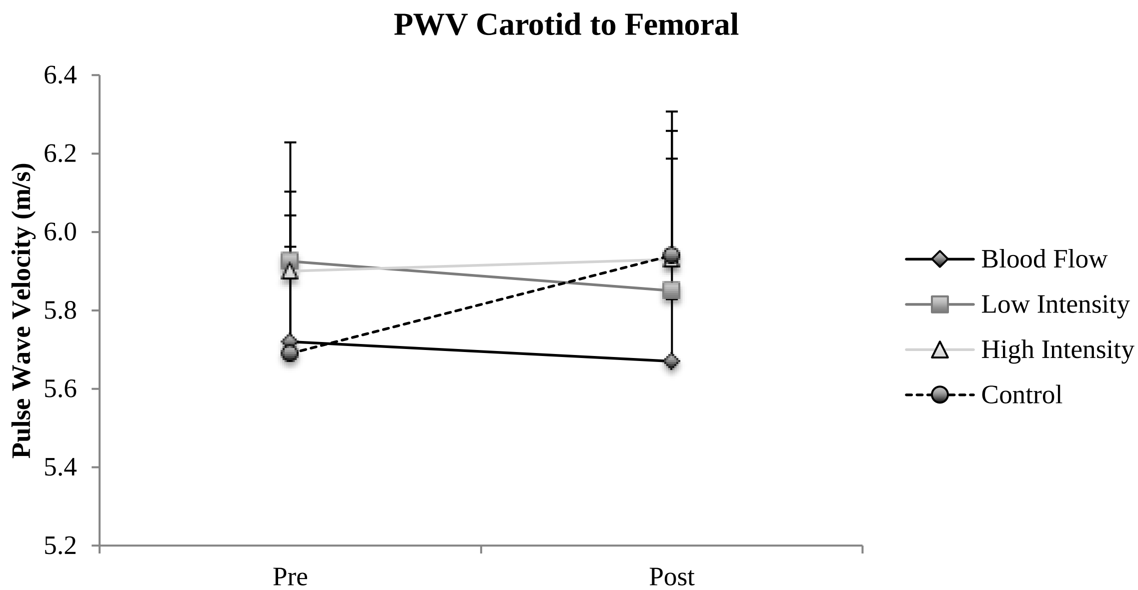
Figure 18. PWV Carotid to Radial



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 19 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on PWV Carotid to Radial in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

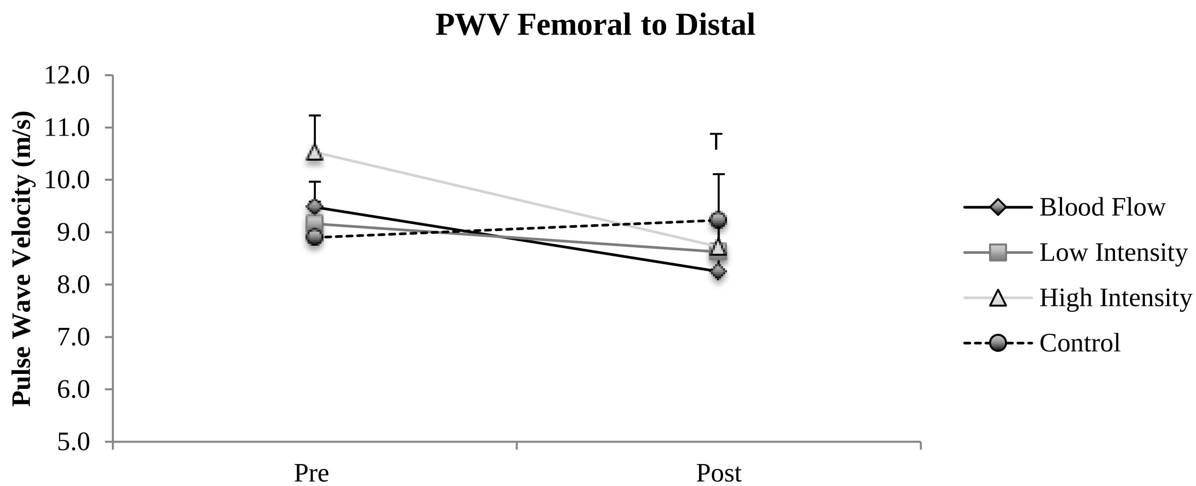
Figure 19. PWV Carotid to Femoral



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

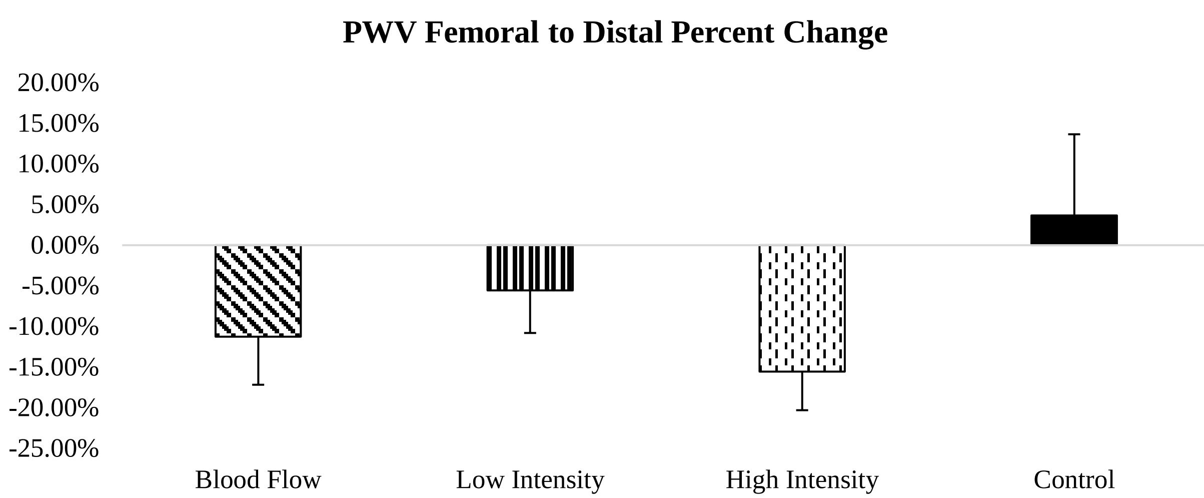
Figures 20 and 21 shows the effects of a six week short-term endurance exercise with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on PWV Carotid to Radial in males. Repeated measures ANOVA found a significant time main effect ($p<.05$) with a decrease from pre to post-training in all groups. All other categories were statistically similar ($p>.05$) for all effects and interactions and were reported together.

Figure 20. Femoral to Distal



Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). [T] Represents significant time difference (p<.05). Values reported as mean ±SE.

Figure 21. PWV Femoral to Distal Percent Change

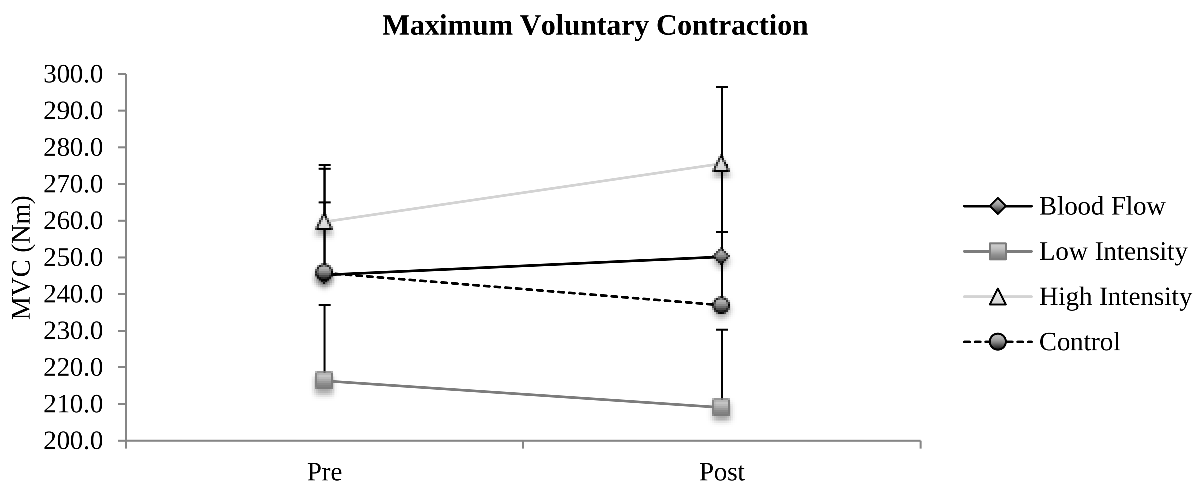


Males (N=39), Blood Flow (N=10), Low Intensity (N=8), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Electromyography

Figure 22 shows the effects of a six-week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on maximum voluntary contraction (MVC) RMS and median frequency in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

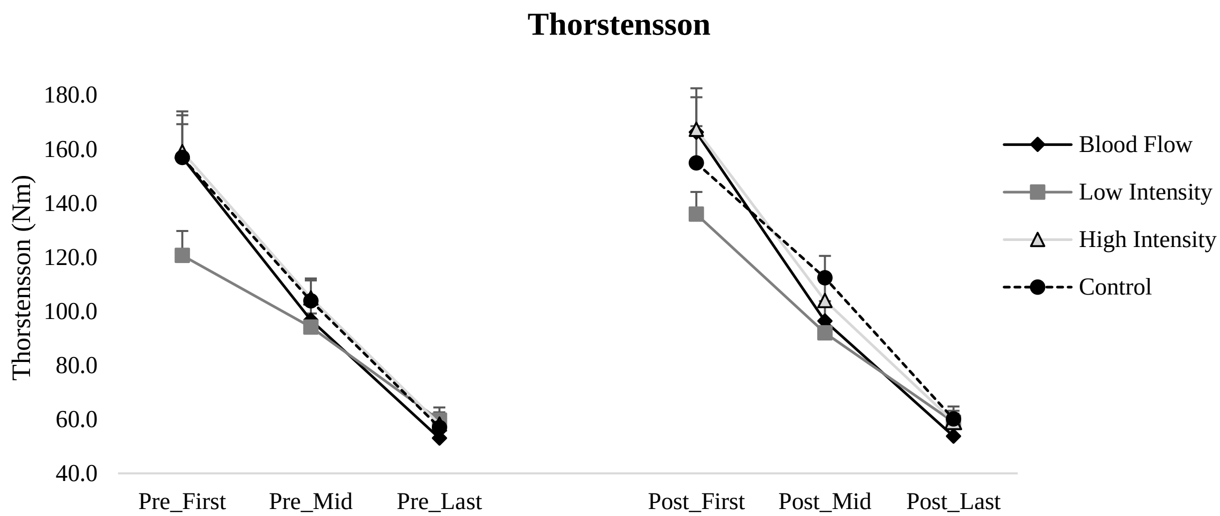
Figure 22. Force Values in Newton Meter During Maximum Voluntary Contraction



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 23 shows the effects of a six week short-term endurance exercise with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on Thorstensson in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

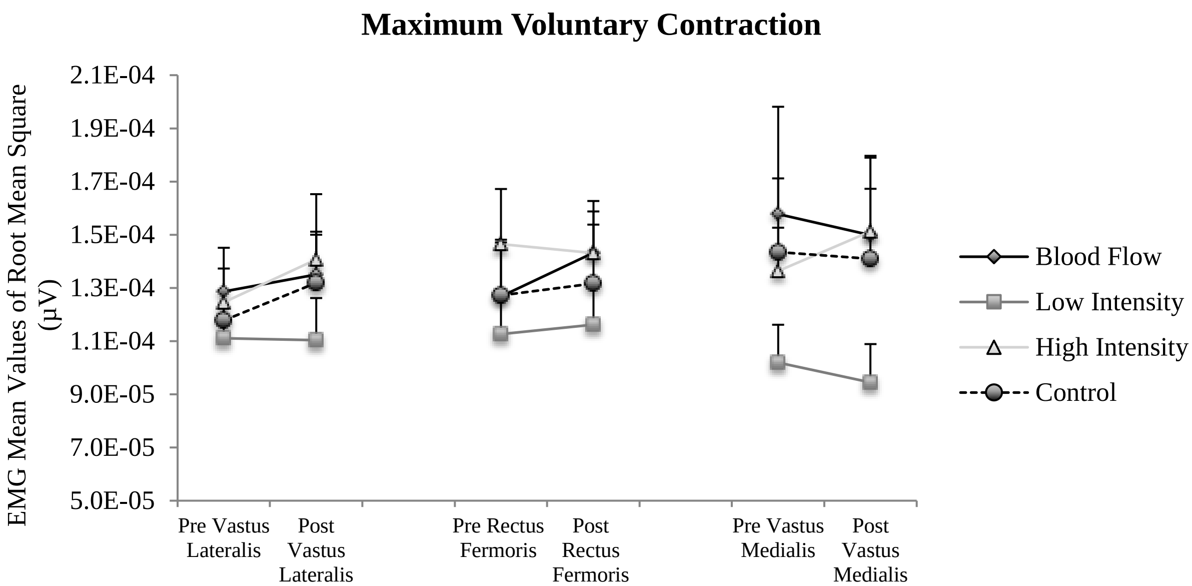
Figure 23. Force Values in Newton Meter During Thorstensson Test



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 24 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG mean value of root mean square in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

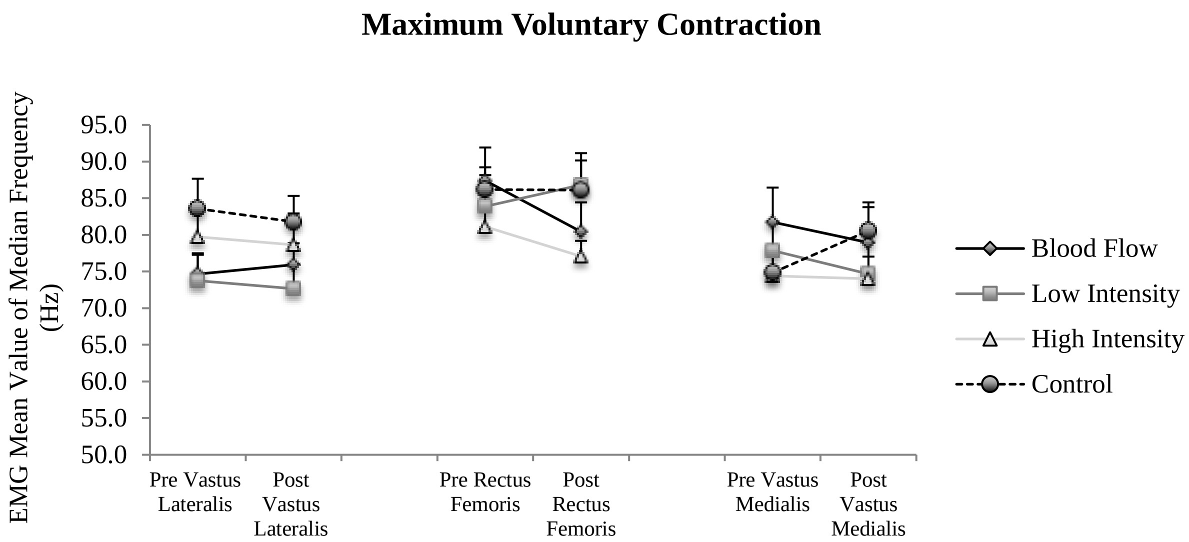
Figure 24. EMG Mean Values of Root Mean Square



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 25 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG mean value of median frequency in males. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

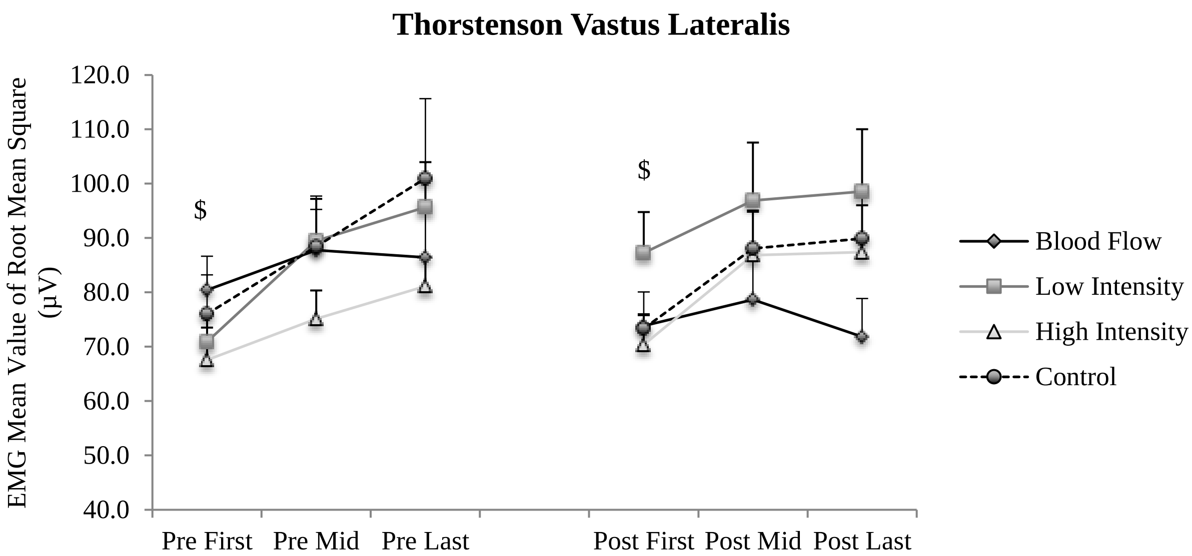
Figure 25. EMG Mean Value of Median Frequency



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

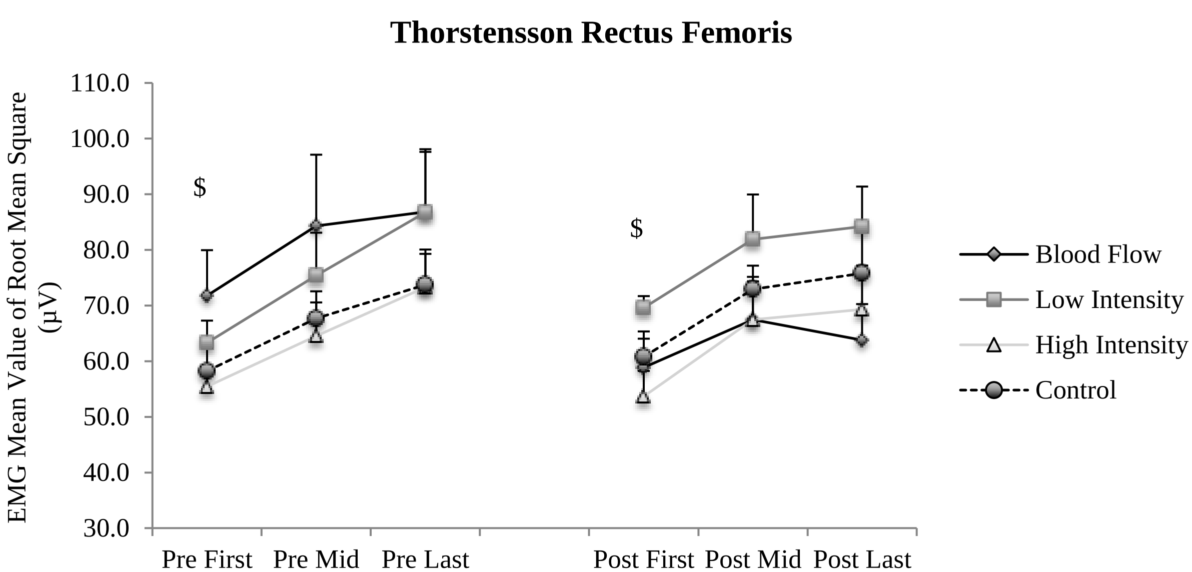
Figures 26, 27 and 28 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG mean value of cyclical analysis on the vastus lateralis, rectus femoris, and vastus medialis muscle while performing Thorstensson on Biodex. RMS values of Thorstensson were normalized against MVC RMS values for each specific muscle group. Repeated measures ANOVA found significant repetition main effect ($p<.01$) for all three muscle groups with the first repetition being significantly higher than the middle and last repetition. All other categories were statistically similar ($p>.05$) for all effects and interactions and were reported together.

Figure 26. Mean Value of Root Mean Square



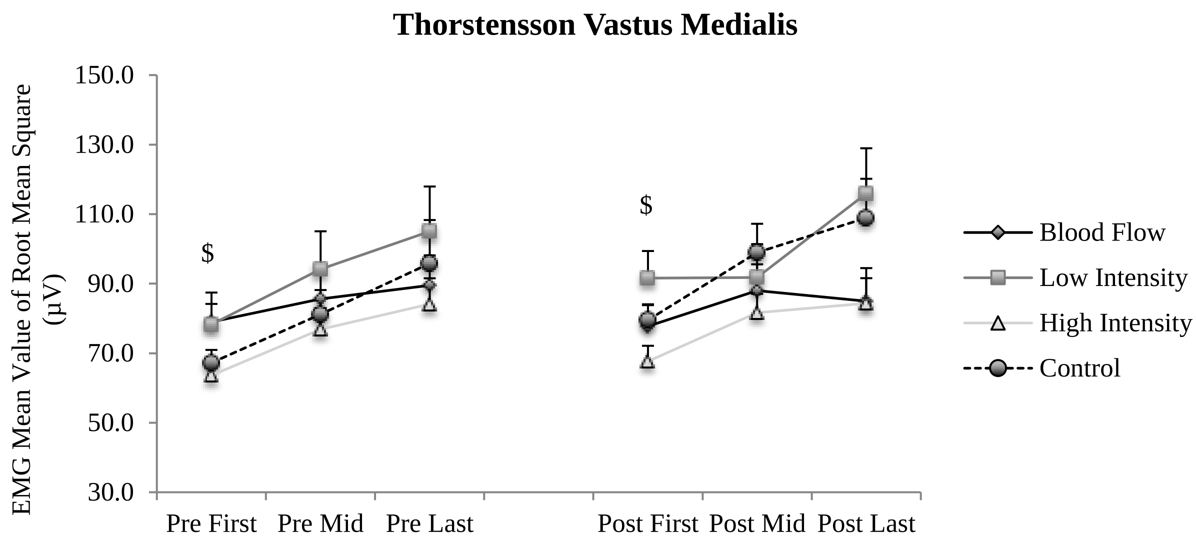
Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

Figure 27. EMG Mean Value of Root Mean Square



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01).Values reported as mean ±SE.

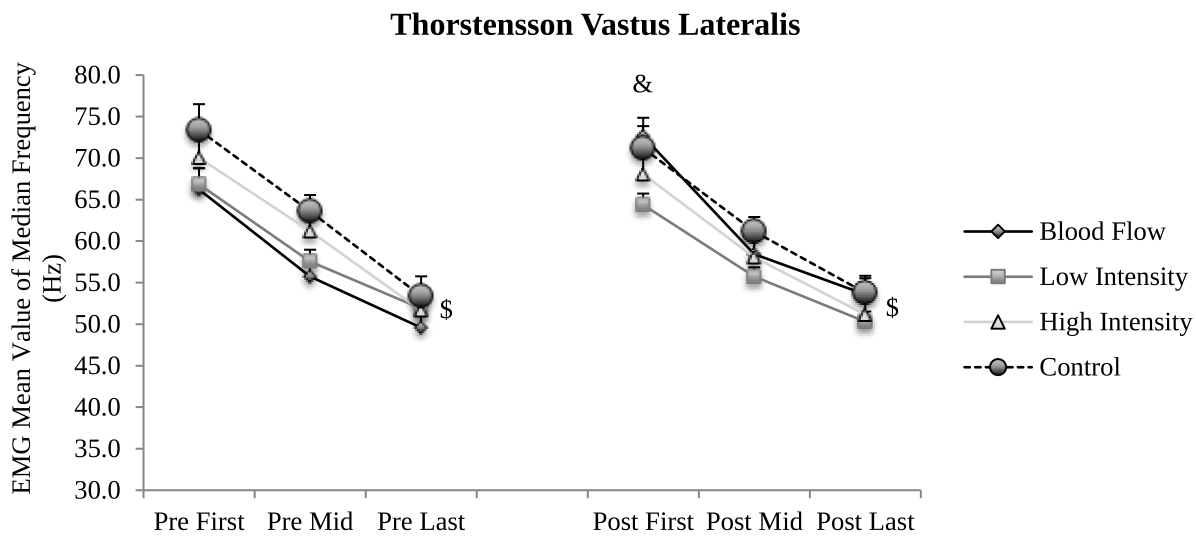
Figure 28. EMG Mean Value of Root Mean Square



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

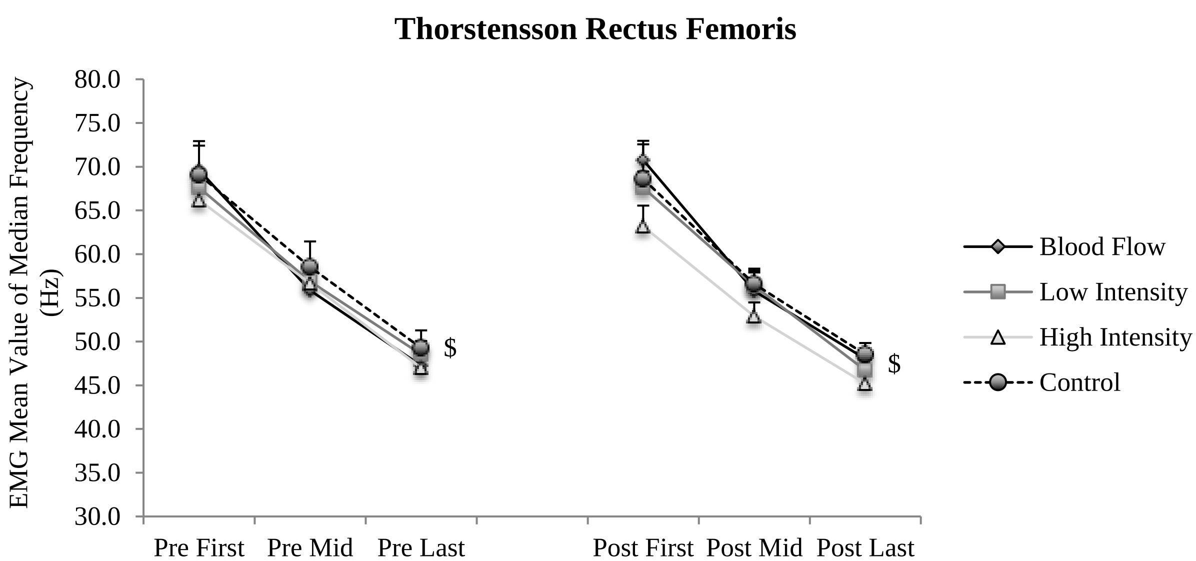
Figures 29, 30, and 31 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG mean value of median frequency on the vastus lateralis, rectus femoris, and vastus medialis muscle while performing Thorstensson on Biodex. Repeated measures ANOVA found significant repetition main effect (p<.01) for all three muscle groups with all repetitions being significantly different. There was a significant interaction between time and group (p<.01) in vastus lateralis for the BFR group from pre to post-training. All other categories were statistically similar (p>.05) for all effects and interactions and were reported together.

Figure 29. EMG Mean Value of Median Frequency



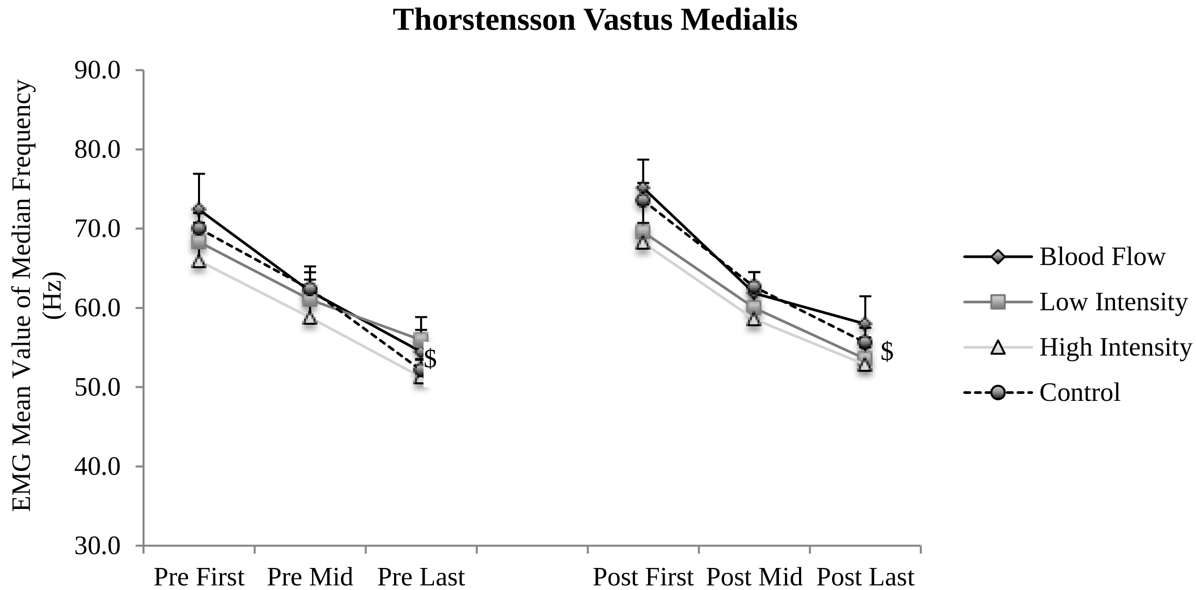
Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). & Significant interaction between time and group for BFR (p<.01). Values reported as mean ±SE.

Figure 30. EMG Mean Value of Median Frequency



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

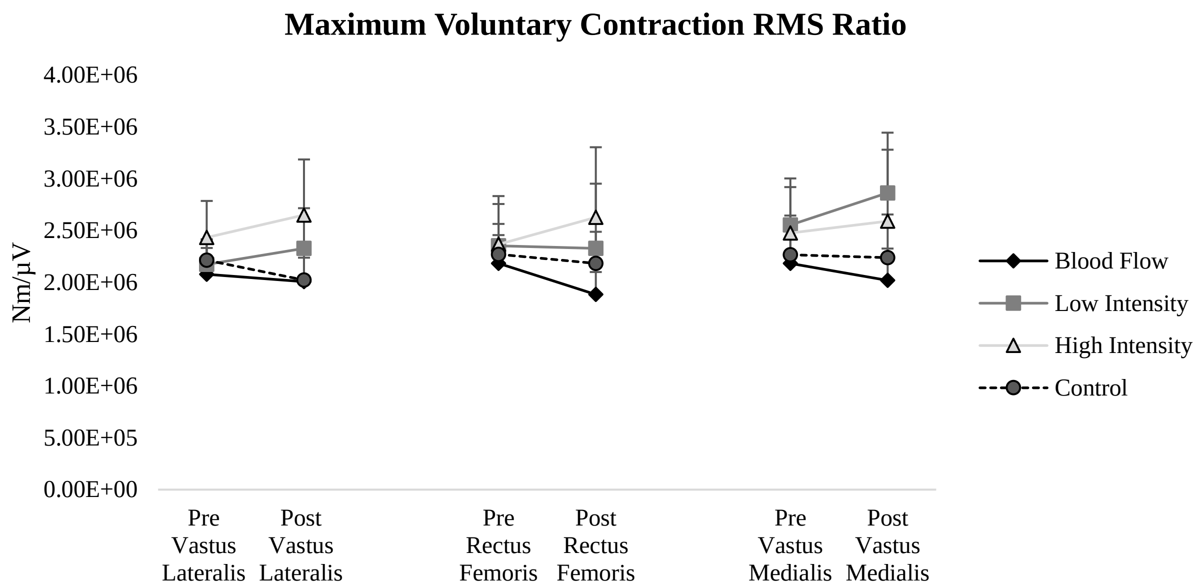
Figure 31. EMG Mean Value of Median Frequency



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

Figure 32 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG/force ratio for RMS in males. All categories were statistically similar (p>.05) for other all effects and interactions and were reported together.

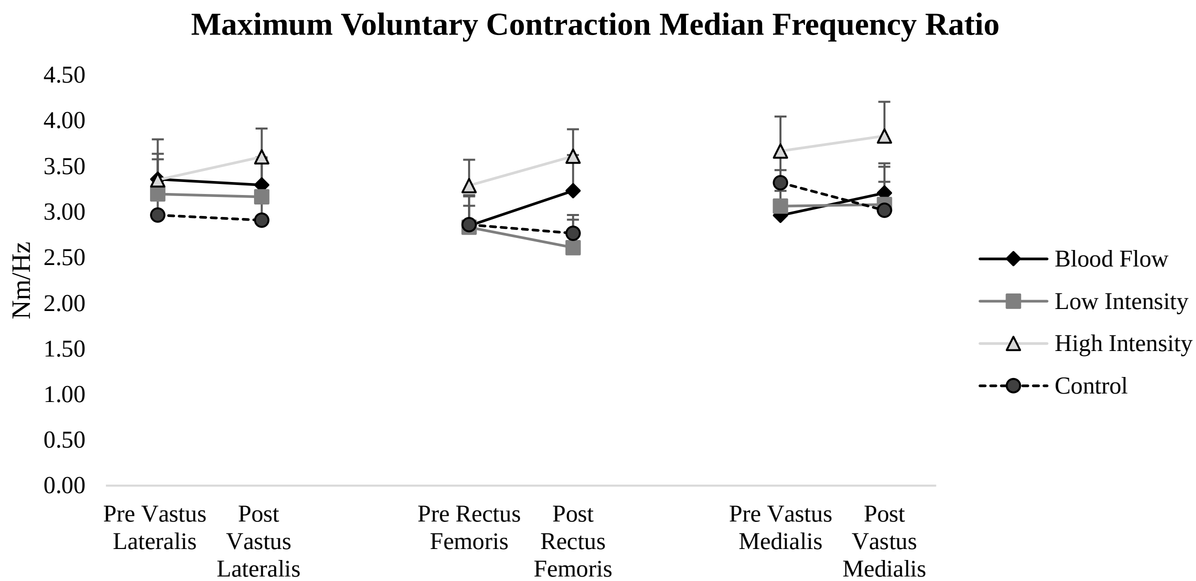
Figure 32. MVC Force/EMG Ratio for RMS



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

Figure 33 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG/force ratio for median frequency in males. All categories were statistically similar (p>.05) for all other effects and interactions and were reported together.

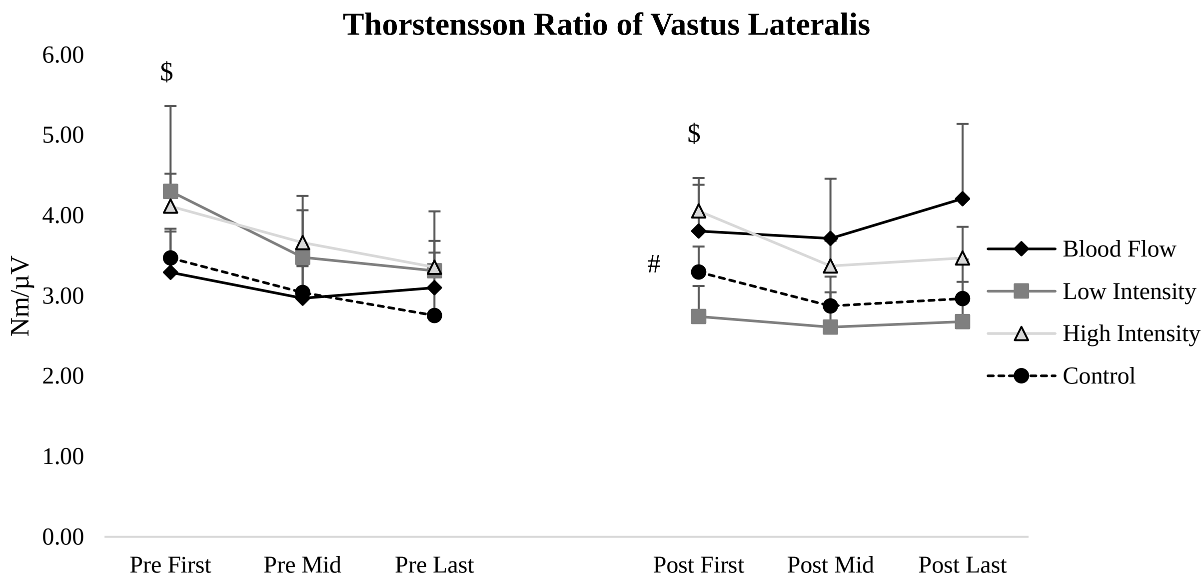
Figure 33. MVC Force/EMG Ratio for Median Frequency



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). Values reported as mean ±SE.

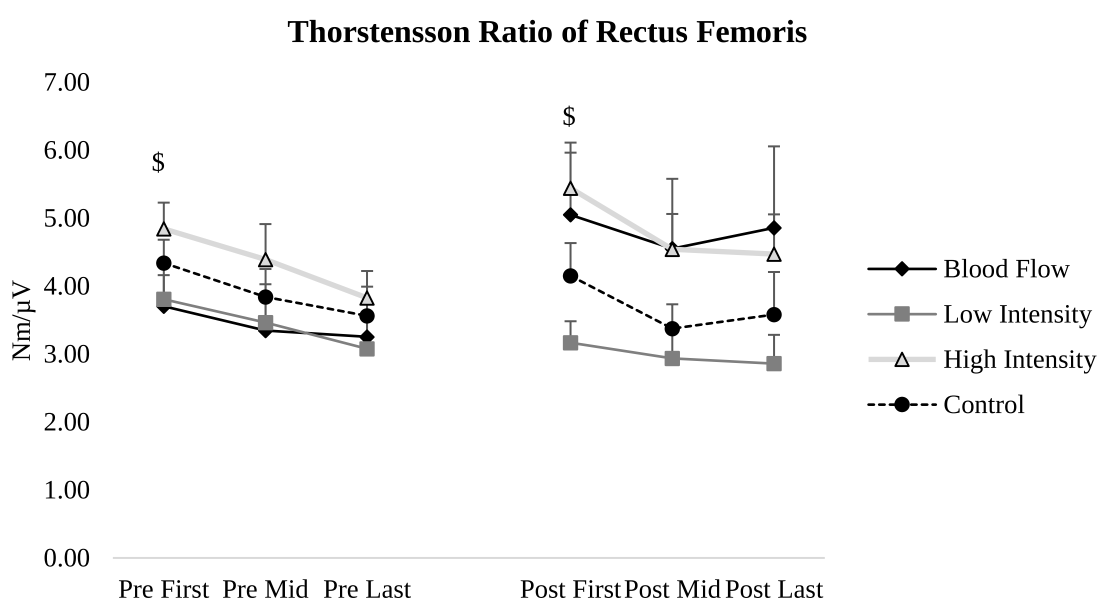
Figures 34, 35 and 36 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG/force ratio for RMS in males. Repeated measures ANOVA found significant repetition main effect ($p<.01$) for all three muscle groups with the first repetition being higher than the middle and last repetition. Vastus lateralis had a significant interaction between time and repetitions ($p<.03$) with a decrease from pre to post-training. All categories were statistically similar ($p>.05$) for all other effects and interactions and were reported together.

Figure 34. Thorstensson Force/EMG Ratio for RMS



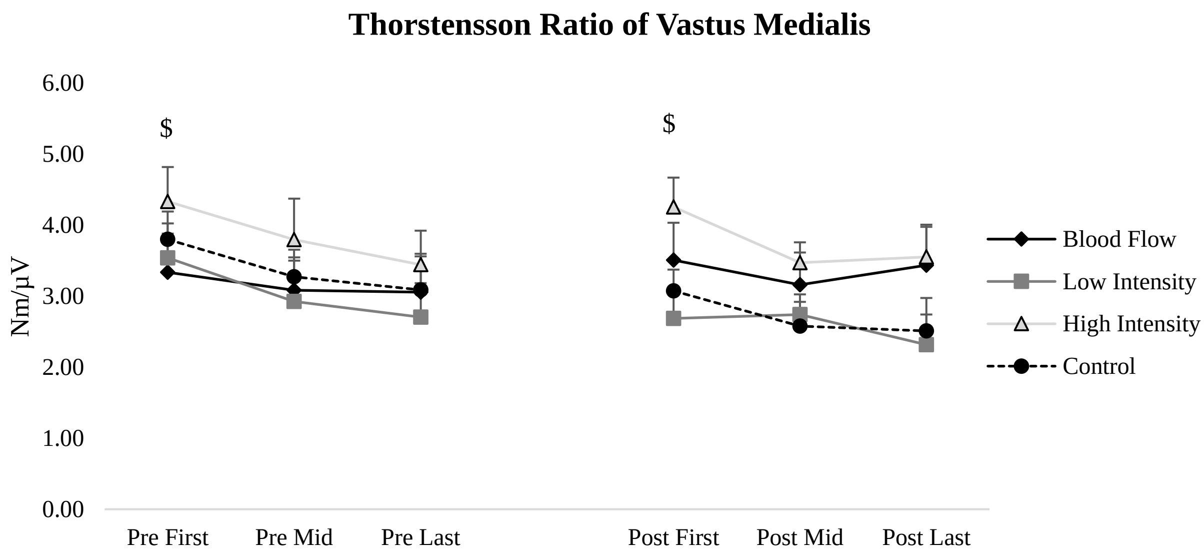
Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). # Interaction between time and repetitions (p<.05)

Figure 35. Thorstensson Force/EMG Ratio for RMS



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

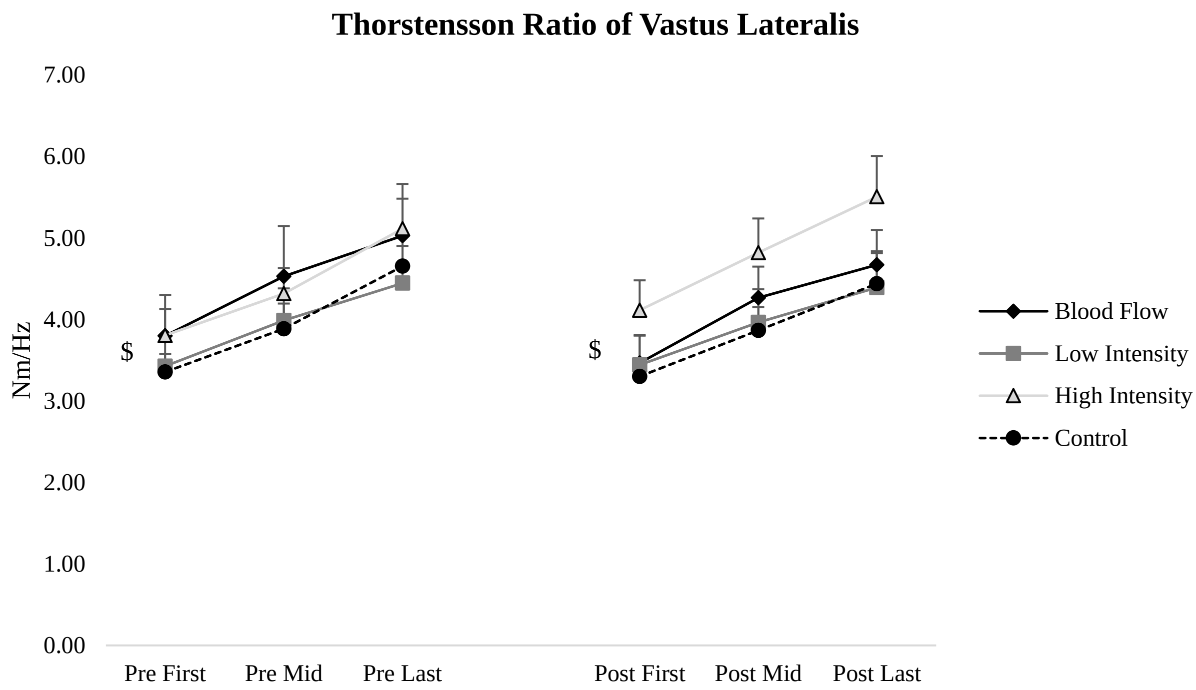
Figure 36. Thorstensson Force/EMG Ratio for RMS



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

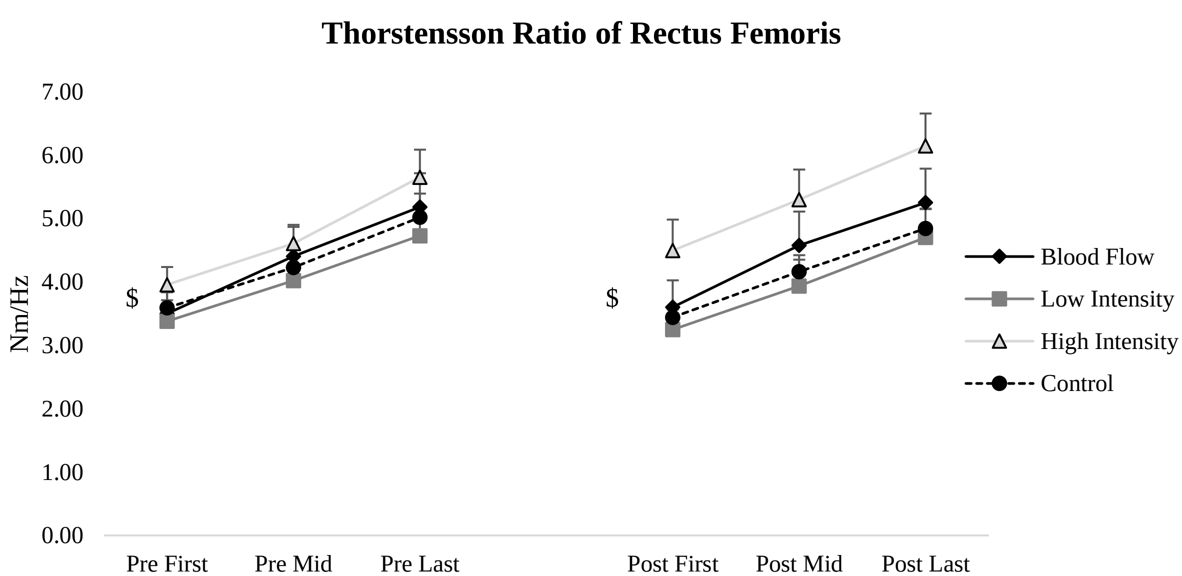
Figures 37, 38 and 39 shows the effects of a six week short-term endurance exercise training study with BFR cuffs at low intensity, without BFR cuffs at low and high intensity and a control group that performed no training on EMG/force ratio for median frequency in males. Repeated measures ANOVA showed significant repetition main effect (p<.01) with significant differences between all repetitions for all muscle groups. All categories were statistically similar (p>.05) for all effects and interactions and were reported together.

Figure 37. Thorstensson Force/EMG for Median Frequency



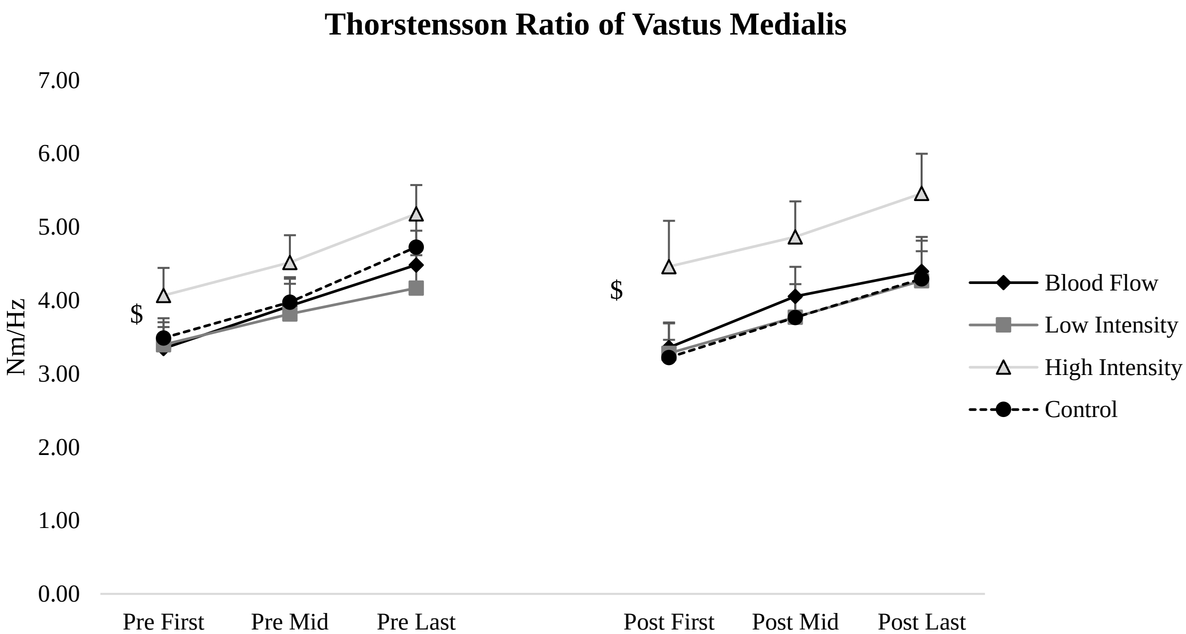
Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

Figure 38. Thorstensson Force/EMG Ratio for Median Frequency



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

Figure 39. Thorstensson Force/EMG Ratio for Median Frequency



Males (N=41), Blood Flow (N=10), Low Intensity (N=10), High Intensity (N=11), Control (N=10). $ Significant repetition differences (p<.01). Values reported as mean ±SE.

CHAPTER V

DISCUSSION

The key findings of this study are as follows: First, the BFR group showed a higher max heart rate and VO_2 when compared to the control group, which may have been caused by the increased workload the cuffs created in addition to the control group not participating in the training program. Second, there was an increase from pre to post-training in cardiac ejection time for BFR. Third, pulse wave velocity at the femoral to distal site was found to have significant time main effects from pre to post-training; which may have been due to differences in vessel wall distension of the central and peripheral arteries (e.g. elastin and collagen).

The analysis of electromyography (EMG) found a significant repetition difference. The first three repetitions performed in Thorstensson was less than the mid three and last three repetitions for the mean value of RMS for the vastus lateralis, rectus femoris and vastus medialis of the quadriceps in both pre and post-training. This may have been caused by the fatiguing effect that occurs throughout the 50 repetitions the Thorstensson test calls for (Thorstensson & Karlsson 1976).

Significant time and group interactions was found in median frequency when examining the mean value of the vastus lateralis; the BFR group had an increase in post-training first repetition values when compared to pre-training values, which did not occur for the other groups. An increase in median frequency is typically seen with a greater percentage of fast twitch fibers, this will create a greater initial values as well as a greater decrease in median frequency (Kupa et al., 1995). However, the present study did not find significant changes in fiber type percentage, which may suggest changes were due to neural adaptations. Significant repetition main effects were also noted for all three muscle groups in median frequency; all repetitions were significantly different from each other. This is to be expected since the test was fatiguing in nature and would produce changes in firing rate.

When the ratio of force values of MVC (Nm) and mean values of EMG RMS (µV) was applied to the first, middle and last repetitions of Thorstensson, significant repetition main effect were found for vastus lateralis, rectus femoris and vastus medialis with the first repetition being higher than the middle and last repetitions for pre and post-training. Additional findings for the force / EMG RMS ratio found a significant interaction between time and repetitions for vastus lateralis. Post-training values for the vastus lateralis ratio had a decrease in the first repetitions of Thorstensson when compared to pre-training values. While there were no significant changes in force values, the decrease in the force (Nm) / EMG (µV) ratio, this may have been caused by an increase in fiber recruitment. Although there was no significance seen in muscle fiber type composition, a shift towards Type I muscle fibers typically occurs with aerobic training (Holloszy& Coyle 1984; Zierath & Hawley 2004), which may explain the decrease in the force (Nm) / EMG (µV) ratio. Since aerobic muscle fibers are smaller and create less force compared to anaerobic muscle fibers (McArdle, Katch F.I & Katch V.L, 2015), it could be speculated that the increases in aerobic fiber recruitment to perform the same work could be one of the responsible factors for the changes in the ratio of force (Nm) / EMG (µV). When the ratio of force (Nm) / median frequency (Hz) for Thorstensson was examined, a significant repetition main effect was found in all three muscle groups with all repetitions being significantly different from each other; this supports findings from the EMG median frequency analysis of Thorstensson.

Hemodynamic Responses

Cardiac ejection time increased from pre-training to post-training in the BFR group. Commonly referred to as left ventricular ejection time, cardiac ejection time occurs when blood begins at the left ventricle with aortic valve opening and ends with aortic valve closure (Stedman, 2012). An increase in ejection time is typically seen with augmentations to vascular resistance and afterload, which is related to aortic pressure. Studies have shown that determining ejection phase indices are related to afterload with shortening of muscle fibers (Corin et al., 1987; Ross 1983; Ford 1980); the present study did not show any significant differences in vascular resistance. Additionally, adaptations from aerobic exercise typically result in an increase in stroke volume, which is the amount of blood ejected per beat by the left ventricle into the aorta (Blomqvist & Saltin, 1983; Nadel 1985). However, no significant changes in stroke volume occurred during this study. It may be possible that while there were no significant changes seen in vascular resistance and stroke volume, perhaps the effects of these two factors were enough to alter ejection time for BFR. Alterations to these factors have occurred with BFR training (Renzi et al., 2010; Abe et al., 2010). An increase in stroke volume would suggest that more blood being ejected would result in increased time from aortic valve opening to aortic valve closing.

Heart rate is known to increase in response to exercise intensity and duration. Exercise induces changes in autonomic activity causing increases in sympathetic activity. This leads to an increase in HR, resulting in a decrease in parasympathetic activity (Smith, Guyton, Manning, &

White, 1976; Victor, Seals, & Mark, 1987). The present study found a significant increase in post-training heart rate max in the BFR group when compared to control. It can be speculated that this change was most likely due to a higher percentage VO_2 max used for speed and a greater final pressure of pneumatic cuffs placed on individuals, which caused a significantly greater heart rate change due to increased workload than the other training groups. Previous studies and text book have shown maximum heart rate has little to no adaptations, typically due to increases in stroke volume, allowing the heart to work more efficiently (Blomqvist & Saltin, 1983; Saltin 1985; Kuipers, 2005; McArdle, Katch F.I & Katch V.L, 2015). Literature has shown that BFR sessions have lower stroke volumes and higher heart rates, in a relatively young population, than the control sessions (Renzi et al., 2010; Sugawara, 2010; Takano et al., 2005), and state that aerobic exercise with BFR requires greater cardiac work. In addition, plasma concentrations of lactic acid are known to be higher when exercising with BFR cuffs, which is known to stimulate chemoreceptors (Takarada, Nakamura et al., 2000; Takarada, Takazawa et al., 2000), subsequently increasing heart rate and cardiac contractility (Hayes et al., 2009). While the previously mentioned studies were acute, Abe et al., (2010) found no significant differences in maximum heart rate between the BFR aerobic training group and control group. Currently, there are a lack of studies investigating the cardiovascular hemodynamic changes that occur with BFR training. It can be speculated that increases in max HR for this study may have been due to subjects having an increased toleration to perception of discomfort/pain caused by metabolic by-products (Chalaye et al., 2013) induced by BFR cuffs, allowing subjects to reach a greater heart rate max when performing VO_2 max testing.

VO_2 was shown to have an increase from pre to post-training in the BFR group when compared to control. Increases in VO_2 typically arise from changes in cardiac output and peripheral adaptations (Sullivan et al., 1988) along with increases in stroke volume and arteriovenous oxygen difference (McArdle, Katch F.I & Katch V.L, 2015). The findings found in this study differ from a study conducted by Abe et al. (2010), which found no changes when it came to aerobic capacity over the 6-week period in the group that wore BFR cuffs. The present study had participants walk for 30 minutes with a 3-minute break to deflate cuffs at the 15-minute mark, and used a speed that was based on 30-40% of an individual's VO_2 max (average speed was 80 m/min), while the study conducted by Abe and colleagues had all participants walk at a constant speed of 67m/min for 20 mins. It is a possibility that the increased time and speed along with a greater final pressure, of the cuffs, was enough to create peripheral adaptations and increase systemic arteriovenous oxygen; which may have caused a redistribution of cardiac output to working skeletal muscles (Blomqvist & Saltin, 1983; Clausen & Trap-Jensen, 1970; Clausen 1976). Studies conducted by Takarada, Nakamura, et al. (2000) and Takarada, Takazawa, et al. (2000) stated that the pressure from BFR cuffs induces ischemia in muscles. Furthermore, Neto et al. (2016) found evidence of decreased SpO_2, which is indicative of a hypoxic environment. During the course of the six-week training, the lower body musculature may have become more efficient at extracting oxygen, which would result in an increase in arteriovenous oxygen difference. This could potentially explain the increased augmentation to subject's maximal oxygen consumption more so than the other conditions that wore no cuffs.

Arterial Compliance

Pulse wave velocity (PWV), at the lower peripheral femoral to dorsalis pedis (pfdPWV) site, was found to have decreased from pre-training to post-training. Studies have shown that moderate-intensity aerobic exercise training can reduce central arterial stiffness in healthy sedentary people (Tanaka, Dinenno et al., 2000; Tanaka, DeSouza et al., 1998). Conversely, the effects of exercise training on peripheral arterial stiffness are not conclusive (Hayashi et al., 2005). Dinenno et al. (2001) found significance that a moderate-intensity aerobic exercise program can induce arterial remodeling of the femoral artery. In addition, Hayashi et al. (2005) found changes in femoral artery diameter with no changes in femoral arterial compliance following aerobic exercise training; it could be speculated that while changes occurred to the peripheral conduit artery, it was not substantial enough to reduce arterial stiffness. One probable explanation for the physiological mechanisms of these changes could be tied to the collagen and elastin content of the peripheral arteries being far less than that of the central arteries (Nichols et al, 1998; Hayashi et al., 2005). The difference in vessel wall distension of the central and peripheral arteries may be a result of site specific adaptations towards the improvement of arterial stiffness that occur with exercise training; which for this present study consisted of using the lower body musculature for running or walking. This could possibly explain the causes for the decrease in pdfPWV from pre to post-training seen in this study.

Electromyography

Prior studies have shown increases in muscle size and strength changes caused by the use of BFR cuffs in a resistance training program (Abe, Yasuda et al., 2008; Yasuda et al., 2011; Fujita et al.,2008). In addition, previous studies conducted by Abe, S. Fujita et al. (2010) and Abe, Sakamaki et al. (2010) found changes in isometric strength induced by 6 weeks of aerobic exercise. However, this present study did not find significant changes in MVC torque, RMS and MDF values during MVC. There was a significant difference in repetitions with the first repetition being less than the middle or last repetitions for the mean value of Thorstensson RMS for pre and post-training. This was observed in all conditions and in all three muscle groups (vastus lateralis, rectus femoris, and vastus medialis). For this analysis, mean value is the average of the periodic cyclic maximum for each repetition that was performed and was normalized to MVC RMS values; for this study first, middle, and last equaled the total of three repetitions. This was likely due to the fact that Thorstensson is an isokinetic fatigue inducing test used to determine muscle fiber type percentage by performing 50 repetitions at 180˚/s of a person's range of motion for extension and flexion at the knee. Because of the nature of the test, a decline in force would be expected to occur from the first, middle, and last repetitions for all groups. An outcome of the properties of muscle fibers innervated by different motor neurons causes the sequence in slow-contracting and fatigue resistant type 1 fibers being recruited before fast-contracting fatigable type 2 fibers (Duchateau, Semmler, & Enoka, 2006). This is an expected response of any exercise that induces fatigue since the active muscle will recruit more motor units in response to a reduction in force production from motor units. Studies have shown that exercise training induces skeletal muscle cell remodeling, which leads to an increase in oxygen uptake, substrate oxidation, and resistance to fatigue (Gielen et al., 2001; Hambrecht et al., 1998; Booth & Thomason 1991). Nevertheless, since there were no changes seen between groups, it is possible that 6 weeks of endurance training, 3 times a week, was not enough to elicit significant differences between the groups.

Analyzing median frequency has allowed for a noninvasive and localized method of observing electrophysiological fatigue processes within a specific muscle group. (Kupa et al., 1995). This study found that the first, middle, and last repetitions were significantly different from each other for the mean value of median frequency when performing Thorstensson, on Biodex, in all three muscle groups. As mentioned earlier, this was likely due to the fatiguing effects of this test, which can cause a decrease in force production as repetitions progressed. Kupa et al. (1995) stated that muscles that have a greater percentage of fast twitch fibers will have a greater initial value as well as a greater decrease in median frequency. Warren et al. (2000) supported findings by Kupa et al. by stating that a decrease in median frequency could be due to increased activation of slower motor units in combination with a decreased activation of fast motor units. This could account for the different variations between the first, middle and last repetitions. Additionally, training may have not been demanding or long enough to elicit changes within muscle fiber type over the course of the 6-week training; as adaptations during the 8 weeks of training neural factors account for approximately 90% of the strength gained (McArdle, Katch F.I & Katch V.L, 2015).

There was an interaction between time and group with an increase in the first repetition followed by a decrease in the middle and last repetitions in post-training for the BFR group; in the mean value of median frequency of the vastus lateralis. This study showed an increase in frequency from pre to post-training, although there were no significant changes in muscle fiber type or body composition after six weeks of training, it can be speculated that BFR possibly resulted in a greater neural adaptation compared to the other conditions. Karabulut et al. (2013) evaluated the effects of different initial cuff pressures (40-45 mmHg and 60-65 mmHg), when performing leg extension on a dynamometer, with EMG recorded at the vastus lateralis. Findings revealed that while there was an increase in motor unit activation for both conditions, significantly higher values were found in the condition that had a higher initial pressure (tightness of the cuffs before inflation). This current study used similar initial pressures and higher final pressures than used in previous studies. Other studies have shown that muscle activation has been shown to increase during low-load exercise with BFR (Takarada et al., 2000; Yasuda et al., 2008, 2009). Furthermore, research also suggests that BFR during low-load aerobic exercise can induce small but significant morphological changes to the muscle (Scott et al., 2014). It can be inferred that the increase in muscle ischemia (Takarada, Nakamura, et al., 2000; Takarada, Takazawa, et al., 2000) from the cuffs creates a hypoxic environment that could change the pattern and level of contribution of different types of muscle fibers resulting in a greater and/or faster neuromuscular adaptations.

Thorstensson Force/EMG Ratio - EMG shows the electrical contraction of a muscle while force shows the mechanical events of the contraction (Roberts & Gabaldon 2008). For this reason, calculating the ratio of the force-EMG relationship provides a more complete picture of overall changes that occur within the muscle. The ratio for Thorstensson force/RMS EMG values showed a repetition main effect in all three muscle groups where all repetitions were significantly different from each other. Because of these similar findings, it can be inferred that the differences seen in the RMS ratio were caused by changes in RMS values of EMG. Since there were no significant changes in force production values it can be inferred that subjects created the same amount of force with more motor unit recruitment.

The vastus lateralis force/EMG RMS ratio showed a significant interaction between time and repetitions with a decrease in the first repetition followed by little to no change from the middle and last repetition for post-training. This present study found no differences in the force production values or EMG RMS values during Thorstensson. These changes may have been caused by a small shift in muscle fiber type, since adaptations to aerobic exercise typically results in a shift toward Type I endurance muscle fibers. In addition, the structure of Type I fibers has been seen in other studies to fatigue less, thus causing smaller changes in EMG at submaximal intensities (Linssen, Stegeman et al., 1991; Linssen, Merks et al., 1991), which would explain how subjects were able to maintain force production during the middle and last repetitions. Furthermore, a study conducted by Gerzˇevic et al. (2011), which looked at the differences in muscle activation between sub-maximal and maximal rowing tests found that the vastus lateralis was responsible for the maintenance of pace in submaximal tests, and had the greatest changes in activation. This could be one explanation for why this was seen in the vastus lateralis and not the other muscle groups examined in this study. Moreover, the fact that this study was a short-term aerobic study could explain why there were no changes in force since changes in strength are typically not seen in short-term aerobic training. In addition, while no differences were seen in condition one speculation could be that, motivation of the subjects may have changed from pre to post-testing. While subjects were instructed on how to perform tests during pre-testing and post-testing, both internal and external motivation may explain why subjects performed better post-training. External motivation in the form of positive feed-back was given to all subjects during pre-testing and post-testing, but multiple studies have shown that intrinsic motivation coupled with positive feed-back increases subject's performance (Vallarand & Losier 1999; Vallarand & Reid, 1984; Vallarand 1983). It is safe to speculate that subjects in control group tried harder during post-testing due to their competitive nature.

The ratio of Thorstensson force/median frequency showed significant repetition main effects for all three muscle groups examined in this study. Repetitions were significantly different from each other, as was reported in EMG values of median frequency, which would account for the increase in the ratio as repetitions progressed. The increase in ratio is most likely due to the decrease in frequency, Warren et al. (2000) stated that a decrease in median frequency could be due to increased activation of slower motor units in combination with a decreased activation of fast motor units. In 2007, Coorevits et al stated that fatigue causes a decrease in the frequency of the EMG signal, typically described as a decline of median frequency parameters of the EMG power spectrum. While no changes were seen in force, changes in EMG will begin to show in the muscles even when the force of the contraction is maintained (De Luca, 1984). For this study no significant changes in force were seen however, changes in median frequency are more detectable before reductions in force occur, which provides an explanation to the increase in ratio as repetitions progress.

Conclusions

The purposes of this study were to 1) Determine if subjects who were assigned to the blood flow restriction group would have greater EMG activity following training. 2) Determine if subjects who were assigned to the blood flow restriction group would perform better in post-training VO_2 testing than those in the ACSM guideline groups. 3) Determine if blood flow restriction would result in better arterial elasticity and compliance post-training than ACSM guidelines. Furthermore, the purpose of this study was to determine if there were changes in small and large arterial elasticity following the use of BFR cuffs during aerobic exercise when compared to a higher intensity session without BFR. 4) To determine if changes occurred in RHR (resting heart rate), SBP (systolic blood pressure), DBP (diastolic blood pressure), MAP (mean arterial pressure), CO (cardiac output), SV (stroke volume), SVR (systemic vascular resistance) and TVI (total vascular impedance) in recreationally active male subjects following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR. 5) Determine if there would be greater increases in MVC force following the use of BFR cuffs during aerobic training when compared to a higher intensity session without BFR.

The research questions asked were:

1) Did subjects who were assigned to the blood flow restriction group have greater EMG activity than the low and high group?

2) Did subjects who were assigned to the blood flow restriction group perform better in post-training VO_2 testing than those in the ACSM guideline groups?

3) Did blood flow restriction result in better arterial elasticity and compliance than ACSM guidelines?

4) Did subjects who were assigned to the blood flow restriction group perform better in post-training MVC and Thorstensson testing?

Research Hypothesis 1

Differences in EMG activity would be found in the blood flow restriction group when compared the other training groups.

The results acquired from this study only partially support this hypothesis. While there were significant findings in Thorstensson, they were related to repetitions differences between the first, middle, and the last repetitions. Only the median frequency of the vastus lateralis showed a time and group interaction for the BFR group with an increase from pre to post-training. Additionally, there were no significant findings when MVC was analyzed.

Research Hypothesis 2

Subjects in the blood flow restriction group would perform better in post-testing VO_2 testing when compared to the training group that followed ACSM aerobic guidelines.

Findings from this study only partially supported this hypothesis. BFR did have a greater improvement in post-testing VO_2 than the other training groups when compared to the control group that did not participate in the six-week training.

Research Hypothesis 3

Subjects in the blood flow restriction group would have better arterial elasticity and compliance than the other training groups that followed ACSM aerobic guidelines.

Results obtained from this study did not support this hypothesis. There were no statistical differences between groups for pulse wave velocity or arterial elasticity. However, there was a decrease in PWV femoral to distal from pre to post-testing.

Research Hypothesis 4

Differences on Biodex would be seen in the BFR group when performing MVC and Thorstensson.

Findings from this study did not support this hypothesis. There was no statistical significance in force production among any of the four groups.

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APPENDIX A

APPENDIX A

DEFINITIONS

1) **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.
2) **Blood Flow Restriction (BFR):** BFR is a technique that restricts venous blood return during exercise. This process involves cuffs placed over the inguinal crease, to which they are then inflated to a specific pressure. The cuffs are 5 centimeters wide and contain an inflatable bladder.
3) **Arterial compliance:** the measurement of the elastic properties of the arteries, which has an inverse relationship with arterial stiffness.
4) **Hemodynamics:** Analysis of physical aspects of blood circulation and blood flow.
5) **Pulse Wave Velocity:** Noninvasive assessment of arterial compliance in which velocity of blood pressure wave forms traveling between two different sites are measured.
6) **Biodex:** Is a device used to measure power, force, moment force (torque), and calculating muscle fiber type percentages.
7) **EMG:** Measures neural activity in isolated muscles.
8) **Bod Pod:** Gold standard for measuring body fat and muscle mass using air displacement

9) **Hydration:** Hydration status was deemed adequate when urine specific gravity measured 1.010 and lower as determined by a clinical urine refractometer.

APPENDIX A

LIST OF ABBREVIATIONS

ANOVA -Analysis of Variance

BFR -Blood Flow Restriction

CET **-**Cardiac Ejection Time

CO -Cardiac Output

DBP -Diastolic Blood Pressure

HR -Heart Rate

EMG - Electromyography

LAE -Large Arterial Elasticity

MAP -Mean Arterial Pressure

MVC -Maximum Voluntary Contraction

PAR-Q **-**Physical Activity Readiness Questionnaire

PP -Pulse Pressure

PR -Pulse Rate

PWV -Pulse Wave Velocity

SAE -Small Arterial Elasticity

SBP -Systolic Blood Pressure

SV -Stroke Volume

SVI -Stroke Volume Index

SVR -Systemic Vascular Resistance

TVI -Total Vascular Impedance

USG -Urine Specific Gravity

APPENDIX–FORMS

APPENDIX FORMS

1. RECRUITMENT FLYER

UTRGV

MALE PARTICIPANTS NEEDED

You are invited to participate in an IRB approved research training study at the Health and Human Performance Department at the University of Texas Rio Grande Valley at Brownsville. The purpose of the study is to assess the short-term training effects of low intensity aerobic training with and without blood flow restriction compared to high intensity aerobic training, on large and small arterial stiffness, hemodynamics, vascular resistance and muscular adaptations . Total time required for completion of the study is 22 visits for a total of about 16 hours.

Please Contact for additional details:

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APPENDIX FORMS

2. INFORMED CONSENT

University of Texas Rio Grande Valley
Informed Consent Form to Participate in Research

Project Title: The Effects of a Short-Term Endurance Training Program with Blood Flow Restriction Cuffs versus ACSM Recommended Endurance Training on Arterial Compliance and Muscular Adaptations in Recreationally Active Males.

Principal Investigator: Dr. Murat Karabulut
Co-Investigators: Brittany Esparza, Patrick Murphy and Danny Dominguez

Faculty Advisor: Dr. Murat Karabulut
Department: Health and Human Performance

You are being asked to volunteer as a participant for this research study. The study will be conducted in the research laboratory of the Health and Human Performance Department at the University of Texas Rio Grande Valley at the Brownsville campus (M-1 Building, room 216). You have been selected as a participant due to your inquiry or recruitment. After analyzing the health questionnaires you are to fill out, you will be informed whether or not you are qualified to participate in this study.

Please read this form carefully and ask any questions you have before agreeing to participate in this study.

Purpose

The purposes of this study are to: 1. Did subjects who were assigned to the blood flow restriction group have greater EMG activity? 2. Did subjects assigned to the blood flow restriction group have greater increases in power, force and torque? 3. Did subjects who were assigned to the blood flow restriction group perform better in post VO2 testing than those in the ACSM guideline groups? 4. Did blood flow restriction result in better arterial elasticity and compliance than ACSM guidelines?

Number of Participants

60 recreationally active male participants will take part of this study.

Procedures

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

a. You will be required to visit the research labs in the Department of Health and Human Performance 22 separate days for a total time commitment of about 16 hours.

b. On the first visit (about 90 minutes), you will fill out the health status questionnaire and be familiarized with the study procedures. You will also read and sign an informed consent and PAR-Q before any testing takes place (these forms will also be emailed to participants). Participants that answer yes to any PAR-Q question, or have blood pressure at or higher than 140/90 mmHg will be excluded from this study. If the participants qualify they will perform their Vo2 max using Bruce protocol.

All study procedures will be conducted in the Exercise Science Laboratory (M-1 building, room 216). Time schedules will be agreed on by the subject and researcher to when it is most convenient to the subject to be both fasted (for at least 8 hours) and hydrated, for pre and post testing. Hydration will be monitored with the use of a urine refractometer, that will require a subject to provide a urine sample to determine the level of current hydration (hydration is at or below 1.010). This study will be a total of 8 weeks long with weeks 1 and 8 consisting of pre and post testing and weeks 2- 7 consisting of actual training.
On the first day, the participants will fill out questionnaires and will be familiarized with the study procedures before starting the exercise sessions. Participants that answer yes to any PAR-Q question, or have blood pressure at or higher than 140/90 mmHg will be excluded from this study. Following initial screening (PAR-Q and health questionnaire, a copy of both forms will be provided) and familiarization, anthropometric measurements will include, resting heart rate, blood pressure, height, weight, body composition, and thigh circumference. Weight and body fat percentage will be measured using the BodPod (gold standard body composition based on air displacement). Thigh circumference will be taken at the mid-point of the greater trochanter and lateral epicondyle. Inflation of the blood flow restriction cuffs (elastic cuffs that are tightened and filled with air to restrict blood flow) will be based on thigh circumference: <45–50 cm = 120 mmHg; 51–55 cm = 150 mmHg; 56–59 cm = 180 mmHg; and ≥60 cm = 210 mmHg.
Participants will also perform their VO2 max using Bruce Protocol day one will last for a total of 1.5 hours. The second day will consist of collecting measurements using SphygmoCor, HDI, BodPod, and Biodex with EMG, this sessions will last for a total of 2 hours. When performing measurements using SphygmoCor the subjects will lie down in the supine position for a minimum of 10 minutes and baseline arterial elasticity and hemodynamics will be measured using Hypertension diagnostic (noninvasive equipment conducts measurements of arterial stiffness via placing a sensor on the radial artery at the right wrist and a cuff to the left arm to measure blood pressure) and measurement of pulse wave velocity using SphygmoCor (which is conducted noninvasively using a pulse wave velocity analyzer in segmental measures at the carotid, femoral, and the dorsalis pedis while wearing three electrodes on the chest to monitor the heart's electrical activity).
Any sessions prior to the beginning of week 2 will be introductory in nature, including initial paperwork and recording necessary values prior to training. Weeks 2-7 will include the actual training sessions in which each participant will come in and perform the specified routine on the treadmill 3 times a week with at least one day of rest between sessions. Upon finishing the 6 week training program, week 8 will consist of measuring all variables that were recorded in week 1. For pre and post recordings subjects will be required to be fasted and hydrated prior to testing. Once body anthropometric and body composition measurements have been taken, the subject will perform their VO2 max using bruce protocol during their first week and last week.. Heart rate (via Polar chest strap and watch) will be monitored continuously while performing VO2 max testing. This first session will take about 35 minutes.
This study will consist of 4 different groups:
A control group that will only come to the lab for pre and post testing and perform the normal daily routine weeks 2-7.

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Informed Consent Form to Participate in Research

The high intensity training group will train at 60-80% of their VO2 reserve for 30 minutes 3 times a week.
The low intensity training group will train 30-50% of their VO2 reserve for 30 minutes 3 times a week.
The low intensity BFR training group will train at 30-50% of their VO2 reserve for 30 minutes 3 times a week .
The time training will be a total of 9 hours for the 6 weeks of training except for the control group who will only come in for pre and post testing.
Week 8 will consist of measuring all variables that were recorded in week 1 as outlined above and will take the same amount of time.
Minimal Risk: The minimal risk includes discomfort using blood flow restriction cuff (for the 30-minute run/walk sessions) and performing the VO2max test (the subject may feel tired right after the test and feel sore a day after the test). They will be screened in detail before being allowed to participate. If at any time they are unable to complete any task they will be allowed to stop.
The research team is required to calibrate all the equipment (which will be performed regularly according to instructions provided by the manufacture) know how to properly use the equipment, and have all documentation done to conduct research. The research team will conduct measurements on the subject of the same gender.

Length of Participation

You will be required to visit the research labs in the Department of Health and Human Performance on 22 separate days for a total time commitment of approximately 16 hours.

Risks

The study has the following risks:

You understand there are minimal risks to healthy individuals when performing any of the requirements for this project. However, even though these standard protocols have been approved at numerous other institutions and will be performed by qualified and trained personnel. You should be aware of the following: The minimal risk include discomfort using BFR cuff (for the 30-minute endurance sessions) and performing Bruce Protocol.

Benefits : The benefits to participation are: You can receive information about your anthropometric measures such as height, weight, body fat percentage, resting BP and HR. Also, you will obtain information about your cardiovascular health when performing endurance exercise, and arterial health from Pulse Wave Analysis assessment.

Injury

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In case of injury or illness resulting from this study, emergency medical services will be contacted (956-882-3896 or 911). Otherwise first aid will be administered appropriately and if medical assistance is needed they will be aware that it will need to be provided through their personal health insurance. However, you or your insurance company may be expected to pay the usual charge from this treatment. The University of Texas at Rio Grande Valley has set no funds to compensate you in the event of injury.

Confidentiality

In published reports, there will be no information included that will make it possible to identify you without your permission. Research records will be stored securely for 3 years after completion of the study and only approved researchers will have access to the records.

Costs

There is no cost for participation.

Compensation

You will not be monetarily reimbursed for you time and participation in this study. However, you will be eligible for extra credit. A professor can offer extra credits, but there will be alternatives to students who do not wish to participate. The individual can acquire extra credit by means of a written report that is relevant to the class material.

Rights

Refusal to participate will involve no penalty or loss of benefits to which you are otherwise entitled. You can discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled.

Voluntary Nature of the Study

Participation in this study is voluntary. 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.

Waivers of Elements of Confidentiality

Your name will not be linked with your responses unless you specifically agree to be identified. Please select one of the following options

_____ I consent to being quoted directly.

University of Texas Rio Grande Valley
Informed Consent Form to Participate in Research

_____ I do not consent to being quoted directly.

Research Team Qualifications

The research team is required to calibrate all the equipment (will be performed regularly according to instructions provided by the manufacturer), know how to properly use the equipment, and have all documentation done to conduct research. The research team will conduct measurements on the subject of the same gender.

Contacts and Questions

If you have concerns, complaints, or questions about the research and/or the researcher(s) conducting this study you are encouraged to contact the Department of Health and Human Performance to speak to the principal investigator Dr. Murat Karabulut, Ph. D., at (956) 882-7236 or e-mail Murat.Karabulut@utrgv.edu. Or Co-Investigator Brittany.esparza01@utrgv.edu or the research assistants : Patrick Murphy at Patrick.murphy01@utrgv.edu, and Danny Dominguez at danny.dominguez01@utrgv.edu; or the faculty advisor Dr. Murat Karabulut, Ph. D., at (956) 882-7236 or e-mail Murat.Karabulut@utrgv.edu.

Who to Contact Regarding Your Rights as a Participant: This research has been reviewed and approved by the Institutional Review Board for Human Subjects Protection (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) 665-2889 or irb@utrgv.edu.

You are voluntarily making a decision whether or not to participate. Your signature indicates that, having read and understood the information provided above, you have decided to participate. You will be given a copy of this information to keep for your records. If you are not given a copy of this consent form, please request one.

Statement of Consent

I have read the above information. I have asked questions and have received satisfactory answers. I consent to participate in the study.

Signature Date

APPENDIX FORMS

3. PAR-Q

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

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

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

If you answered

YES to one or more questions

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

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

NO to all questions

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

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

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

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

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

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

NAME ________________________________

SIGNATURE ________________________________ DATE ________________________________

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

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

APPENDIX FORMS

4. IRB APPROVAL LETTER

IRBNet Board Document Published

KF Kimberly Fernandez <no-reply@irbnet.org>

Wed 9/21/2016, 9:48 AM

Murat Karabulut; Brittany Esparza

Reply all

Please note that The University of Texas Rio Grande Valley Institutional Review Board has published the following Board Document on IRBNet:

Project Title: [952526-1] The Effects of a Short-Term Endurance Training Program with Blood Flow Restriction Cuffs versus ACSM Recommended Endurance Training on Arterial Compliance and Muscular Adaptations in Recreationally Active Males.
Principal Investigator: Murat Karabulut, Ph.D.

Submission Type: New Project
Date Submitted: August 29, 2016

Document Type: Initial Approval Letter
Document Description: Initial Approval Letter
Publish Date: September 21, 2016

Should you have any questions you may contact Kimberly Fernandez at kimberly.fernandez@utrgv.edu.

Thank you,
The IRBNet Support Team

www.irbnet.org

APPENDIX FORMS

5. DATA COLLECTION SHEETS

HDI/*PulseWave*™ CR-2000

Research CardioVascular Profile Report

Research Subject ID:

Research Subject Name:

Date:
Time:
Age:
Gender:
Height:
Weight:
BSArea:
Body Mass Index:

Average Blood Pressure Waveform

PARAMETER	RESEARCH SUBJECT VALUE
SYSTOLIC BLOOD PRESSURE	
DIASTOLIC BLOOD PRESSURE	
MEAN ARTERIAL BLOOD PRESSURE	
PULSE PRESSURE	
PULSE RATE (beats/min)	
ESTIMATED CARDIAC EJECTION TIME (msec)	
ESTIMATED STROKE VOLUME (ml/beat)	
ESTIMATED STROKE VOLUME INDEX (ml/beat/m^2)	
ESTIMATED CARDIAC OUTPUT (L/min)	
ESTIMATED CARDIAC INDEX (L/min/m^2)	
LARGE ARTERY ELASTICITY INDEX (ml/mmHg x 10) (Capacitive Arterial Compliance)	
SMALL ARTERY ELASTICITY INDEX (ml/mmHg x 100) (Oscillatory or Reflective Arterial Compliance)	
SYSTEMIC VASCULAR RESISTANCE (dyne•sec•cm^{-5})	
TOTAL VASCULAR IMPEDANCE (dyne•sec•cm^{-5})	

Eagan, MN 55121 +1-651-687-9999 Toll-Free: 1-888-*PulseWave* (785-7392)

Form: 00017-001 (Rev. A / 08.Oct. 99) "*For Research Purposes Only*"

APPENDIX FORMS

6. DATA COLLECTION SHEET 2

Pre Test

Name:____ Date:__________

Height:__________________________

Weight:__________________________

EMG Measurements	Initial Measurements	
Vastus Medialis		80%:
Rectus Femoris		50%:
Vastus Lateralis		2/3rds:

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

VO2 max:____________________ % of VO2 max:___________________

VO2 max:________________% of VO2 max:_______________

Date:____________________

USG:_____________________

BodPod	
Weight	
Body Fat%	
Lean Weight	
Fat Weight	

C-R	
C-F	
F-D	

Carotid:__________________

Radial:___________________

Femoral:__________________

Distal:____________________

MVC 1	2	3

APPENDIX FORMS

7. PROFESSOR PERMISSION SCRIPT

The University of Texas Rio Grande Valley
Professor Permission Script

My name is Brittany Esparza/Danny Dominguez/ Patrick Murphy; I am a graduate student and a staff member from the Department of Health and Human Performance at the University of Texas Rio Grande Valley (UTRGV). I would like to ask permission to enter your classroom to invite your students to participate in my research study. My study is about The Effects of a Short-Term Endurance Training Program with Blood Flow Restriction Cuffs versus ACSM Recommended Endurance Training on Arterial Compliance and Muscular Adaptations in Recreationally Active Males.

As part of participation, students will be asked to perform 22 sessions, which will include: A pre and post session in which the student will be asked to come in hydrated (which will be tested via urine sample), 8-hours fasted. These sessions will include body composition testing, anthropometric measuring, hemodynamics, Vo2 max testing, and testing on the Biodex with electromyography sensors placed on student's legs. Students will come to the lab 3 times a week for approximately 30 minutes for each training sessions with or without blood flow restriction cuffs, depending on random assignment for a total of 6 weeks. The total time commitment is 16 hours Participation in this research is completely voluntary; they may choose not to participate without penalty. All data will be confidential by being collected by Brittany Esparza, Patrick Murphy, Danny Dominguez, and Murat Karabulut, and later stored in a locked file cabinet for 3 years.

If allowed, I would like to come in at the beginning of the class time. I will ask you to please exit the classroom prior to and during students' involvement in my study to reduce any possible feeling of coercion to participate in the study.

Extra credit will be offered through participation of the study I will conducting or by means of writing a report that is relevant to the material in the course if the professors choose to offer the extra credit.

This research study has been reviewed and approved by the UTRGV Institutional Review Board for the Protection of Human Subjects (IRB).

If you have questions about the research, please feel free to contact any of us at Brittany Esparza Brittany.esparza01@utrgv.edu, Patrick Murphy at Patrick.murphy01@utrgv.edu, and Danny Dominguez at danny.dominguez01@utrgv.edu; or the principal investigator Murat Karabulut murat.karabulut@utrgv.edu. Or, if you have any questions regarding your students' rights as participants in the study, please call the IRB at (956) 665-2889 or email at irb@utrgv.edu.

APPENDIX FORMS

8. IN-PERSON RECRUITMENT SCRIPT

The University of Texas Rio Grande Valley
Recruitment Script

My name is Brittany Esparza/Danny Dominguez/ Gage Murphy; I am a graduate student and a staff member from the Department of Health and Human Performance at the University of Texas Rio Grande Valley (UTRGV). I would like to invite you to participate in my research study: Effects of a Short-Term Endurance Training Program with Blood Flow Restriction Cuffs versus ACSM Recommended Endurance Training on Arterial Compliance in Recreationally Active Males Muscular Adaptations in Recreationally Active Males.

This research study has been reviewed and approved by the UTRGV Institutional Review Board for the Protection of Human Subjects (IRB).

In order to participate you must be between the ages of 18 and older, not be hypertensive stage 2, and dependent on answers selected on Physical Activity Readiness-Questionnaire and Health Status Questionnaire.

Participation in this research is completely voluntary; you may choose not to participate without penalty.

As a participant, you will be asked to partake in up to 22 sessions (depending on the group you are randomly assigned to), which include two identical pre and post sessions that consist of measuring: resting heart rate, blood pressure, height, and weight, pulse wave velocity, small and large arterial elasticity, and Vo2 max, and testing on Biodex while having a electromyography sensor placed on your legs. For these two sessions, you will be asked to come in hydrated (which will be tested via urine sample) and 8-hours fasted. The middle 18 sessions will consist of 30 minutes of high intensity or low intensity aerobic training on the treadmill with and without blood flow restriction cuffs (depending on the group you are assigned to). The total time commitment is 16 hours. If you start the study and decide you do not wish to continue, you may stop without penalty. All data will be confidential by being collected by Murat Karabulut, Brittany Esparza, Danny Dominguez, and Patrick Murphy and later stored in a locked file cabinet for 3 years.

If you would like to participate in this research study, please e-mail principal investigator Murat Karabulut at murat.karabulut@utrgv.edu, or research assistants Brittany Esparza at Brittany.esparza01@utrgv.edu, Patrick Murphy at Patrick.murphy01@utrgv.edu, and Danny Dominguez at danny.dominguez01@utrgv.edu.

Do you have any questions now? If you have questions later, please contact me by email at brittany.esparza01@utrgv.edu

"You may also contact principal investigator/my faculty advisor Dr. Murat Karabulut, at murat.karabulut@utrgv.edu."

BIOGRAPHICAL SKETCH

Brittany Esparza, Bachelors degree in Exercise Science May 2015 acquired from the University of Texas at Brownsville, Masters degree in Exercise Science July 2017 acquired from the University of Texas Rio Grande Valley ;401 Boca Chica Blvd., Brownsville, Texas 78521