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Comparing Various Physiological System Adaptations Following 8 Weeks of Resistance Training with or Without BFR in Older Males

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COMPARING VARIOUS PHYSIOLOGICAL SYSTEM ADAPTATIONS FOLLOWING 8 WEEKS OF RESISTANCE TRAINING WITH OR WITHOUT BFR IN OLDER MALES

A Thesis

by

RICARDO PARRA

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ABSTRACT

Parra, Ricardo, The effects of a short-term resistance training program with blood flow restriction cuffs versus recommended resistance training on arterial compliance and muscular adaptations in healthy middle-aged and older males. Master of Science (MS), May, 2022, 115 pp., 23 tables, 56 figures, references, 181 titles.

PURPOSE: The purpose of this study was to compare the effects of 8 weeks of resistance exercise training with and without BFR on: 1), arterial elasticity and hemodynamics (e.g., blood pressure and resting heart rate), 2) muscular force production (e.g., maximal voluntary contraction, force production, electromyography, and estimated one-repetition maximum) in males between the 50 to 70 years of age.

RESULTS: Significant condition difference for reflection magnitude occurred in BFR group ($p < 0.05$). BFR reduced reflection magnitude compared to END ($p < 0.05$). Significant time*condition effect occurred in Leg Press 1RM, Leg Extension 1RM, Leg Curl 1RM, Chest Press 1RM, and Shoulder Press 1RM ($p < 0.05$). Significant condition*time interaction occurred for Isokinetic Leg Extension Test (60°/s) ($p < 0.05$). A significant time*condition interaction occurred during Maximal Voluntary Contraction (MVC) –Root Mean Square for both vastus medialis and vastus lateralis ($p < 0.05$). A significant time main effect occurred in the BFR group for the amplitude mean of the MVC in the vastus medialis and vastus lateralis ($p < 0.05$). A significant time main effect occurred for median

frequency of the MVC ($p < 0.05$). A significant condition*time interaction occurred in arm fat percentage ($p < 0.05$). The BFR group had significantly less fat tissue (%) in the left arm ($p < 0.01$) and in the right arm ($p = 0.04$). A significant time main effect occurred in the total lean tissue for the left side of the body ($p = 0.04$).

CONCLUSION: Using BFR resistance training at a low intensity can achieve similar strength and neuromuscular adaptations seen at higher intensities while reducing reflection magnitude, which may improve arterial elasticity over time. In short, BFR with resistance training may provide all the benefits of higher intensity resistance training without any negative effects on arterial health.

DEDICATION

None of this would have been possible without the support of my family. I am dedicating this thesis to my mother, Juani Parra, to my siblings, Damaso Parra III, Javier Parra, and Claudia I. Aldape. I am also dedicating this thesis to my partner, Amanda Davé. I am grateful for her unconditional love, patience, and support. Thank you for never giving up on me.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The older population is growing in the US. The 2010 census showed that there were more people 65 and older than at any previous census (Werner, 2011). This age group grew at a faster rate than the total population between 2000 and 2010. Interventions to improve health and independence could positively impact aging; but many causes of disability in later life are the result of accumulated lifestyle and other risks much earlier in life (Chatterji et al., 2015). Age is one of the major risk factors of cardiovascular disease (Costantino et al., 2016) and probably the most important risk factor affecting the cardiovascular system (Kovacic et al., 2011).

The benefits of exercise on longevity and quality of life are well known (Gremeaux et al., 2012; Ryan, 2010), but adherence to resistance exercise remains low, with lack of time, current or past injury, or perceived difficulty as common barriers (Burton et al., 2017; Picorelli et al., 2014; Rhodes et al., 1999). Designing a resistance training program should address these barriers in order to maximize adherence. Blood flow restriction (BFR) training is one potential method to remove perceived barriers by combining low intensity exercise with blood flow restriction and has existed in some form since the 1960's (Sato, 2005). The technique uses pneumatic cuffs to modulate venous return to the working limbs. Recently published reviews have shown that the concomitant effects of BFR with low-intensity resistance training can produce similar hypertrophic and hemodynamic adaptations to high intensity resistance training

(Centner et al., 2019; Neto et al., 2017; Pearson & Hussain, 2015). In order to reap the benefits of exercise, adherence is crucial. Because BFR training uses light loads, it can be completed in a short amount of time, it can reduce the fear of injury flare-up, and it addresses the perceived difficulty associated with traditional resistance training programs at higher intensities. Therefore, the aim of this study was to investigate the effects of an 8-week resistance training program on hemodynamics, arterial compliance, force production, electromyography (EMG), and body composition, with a focus on modality (i.e., BFR and non-BFR) and intensity (low intensity vs. moderate intensity) in males 50-70 years of age.

Problem and Purpose Statement

Exercise can attenuate the physiological changes that come with aging. Adoption and adhering to an exercise plan come with many obstacles, including self-efficacy, time constraints, and fear of injury. This study aimed to investigate the effects of low-intensity resistance exercise coupled with blood flow restriction versus traditional moderate-intensity resistance training on hemodynamics, arterial elasticity, force production, EMG, and body composition in males aged 50-70 years.

Study Purposes

The goals of this study were to compare the effects of 8 weeks of resistance exercise training with or without BFR on: 1) hemodynamics (e.g., blood pressure and resting heart rate); 2) arterial elasticity (e.g., pulse wave velocity); 3) muscular force production (e.g., maximal voluntary contraction, and estimated one-repetition maximum); 4) EMG (e.g., amplitude of maximal voluntary contraction); and 5) body composition (e.g., dual-energy X-ray absorptiometry, or DEXA) in males between the ages of 50 to 70 years of age.

Significance of the Study

The research is clear: resistance training adaptations can improve multiple physiological functions and health indicators across the lifespan. Although the benefits of resistance training exercise are known, obstacles to adherence to regular exercise training continue to exist regardless of age. What's more, the predictors of exercise adherence cited by younger adults are different in elderly populations (Schutzer & Graves, 2004). Some external barriers that are cited by middle adulthood and elderly adulthood include lack of facilities, lack of time, and "no one to exercise with" (Justine et al., 2013).

Blood flow restriction training has been shown to mimic the hypertrophic effects of traditional resistance training, in less time and with a lower intensity. The purpose of the study was to investigate variables associated with resistance training, which follow a paradigm of chronological order of adaptations starting with initial neural and cardiovascular changes, followed by mechanical and muscular hypertrophic adaptations with consistent exercise. This study will add to the body of knowledge and could also impact future recommendations, offer alternatives, and improve exercise adherence in middle-aged males.

Results from this study helped to provide a clearer picture of the physiological adaptations to BFR exercise and how the adaptations brought about by BFR compare to traditional methods. This study found that BFR resistance training can help maintain arterial elasticity while improving muscle mass and strength in middle-aged males. This information is vital, as it provides another tool for improving or maintaining health outcomes in middle adulthood.

Assumptions

1. All participants would complete the resistance training program and the tests to the extent of their ability.
2. All participants provided true information in all of the forms.
3. Any equipment used was properly calibrated and provided accurate results.
4. No participant would participate in an additional exercise or nutritional program while enrolled in the study.
5. All participants arrived to their testing having fasted for 8 hours and rested.

Limitations

1. The study may not be representative of the population due to all participants having volunteered rather than randomly sampled from the community.
2. The study was limited to males 50-70 years of age and free of diagnosed cardiovascular or metabolic diseases.
3. Health history, medical, and physical activity information was self-reported.
4. Physical activity and nutritional intake were not monitored throughout the study.

Delimitations

1. Signs, symptoms, and a current diagnosis of either cardiovascular disease or any metabolic disease would disqualify participants.
2. Any participant who fell out of the age range was not allowed to participate.
3. Participants who could not complete maximal testing were disqualified from the study.
4. Participants who missed two consecutive training sessions were disqualified from the study.

Research Questions

To test the hypotheses, the following research questions were addressed:

1. Did both training groups significantly improve EMG activity compared to control?
2. Did both training groups significantly improve arterial elasticity compared to control?
3. Did both training groups improve strength gains similarly?
4. Did both training groups significantly improve body composition compared to control?

Hypothesis

1. Both training groups will similarly improve EMG activity compared to control.
2. Both training will significantly improve arterial elasticity compared to control.
3. Both training groups will have similar strength gains.
4. Both training groups will significantly improve body composition compared to control.

Operational Definitions

1. **Arterial compliance:** The ability of the arteries to expand and contract with cardiac palpitation
2. **Biodex:** A device used to measure muscular force production, torque, and provide data to estimate muscle fiber type in participants.
3. **Blood Flow Restriction:** a mode of exercise that modulates venous return in the working muscles during exercise. Venous return is modulated by way of pneumatic cuffs placed at the uppermost portion of the working appendages and inflated to an ideal, final pressure.
4. **Bone mineral density:** a measure of the amount of minerals contained in the bone. Bone mineral density is used to diagnose osteoporosis

5. **Dual-energy X-ray absorptiometry:** an imaging test that uses a very low dose of x-rays to measure bone mineral density; sometimes referred to as bone densitometry, dexa, or dxa.
6. **Electromyography:** a recording of the electrical activity of the muscle tissue.
7. **Estimated visceral adipose tissue:** an indirect determinant of visceral adipose tissue Visceral adipose tissue is the adipose tissue located within the abdomen and surrounding the internal organs. Visceral adipose tissue is strongly associated with other metabolic risk factors.
8. **Hemodynamics:** An analysis of the physical aspects of circulating blood flow.
9. **Hydration:** Hydration was acceptable when a measurement of urine specific gravity was at or below 1.010 as per analysis from a clinical urine refractometer
10. **PAR-Q:** Physical activity readiness questionnaire; a screening tool in the form of 7 questions which determine whether or not a participant can safely participate in physical activity.
11. **Pulse wave velocity:** A noninvasive assessment of arterial compliance; an applanation tonometer is placed at different pulse sites, and the speed is determined by measuring the distance between the sites.
12. **Resistance Training:** resistance training is a mode of exercise in which the muscles contract against an external resistance; following proper guidelines will improve strength indices and lean body mass.
13. **Volume:** a term used to describe the quantification of work performed during resistance training; calculated by multiplying sets by the repetitions by the amount of weight lifted; sometimes also referred to as volume load.

Summary

The population aged 65 and older is expected to be about 61 million people by 2030 and over 100 million people by 2060 (Goldman et al., 2013; Knickman & Snell, 2002). This population growth will be a burden on the healthcare industry. For example, the American Heart Association estimated that medical costs and productivity losses for cardiovascular disease alone will be over $1 trillion by 2035 (Dunbar et al., 2018). In order to reduce the burden, exercise has often been considered as an intervention. There is not a one-size-fits all recipe for physical activity and exercise (Chao et al., 2000). Barriers and motivators for exercise change throughout the lifespan: a young adult might be motivated by improving their physique, while someone older may want to maintain their health (Chao et al., 2000; Schutzer & Graves, 2004).

BFR training has shown to be a promising modality to improve health parameters for older populations, and BFR without resistance training has been shown to maintain muscle strength (Karabulut et al., 2009; Kubota et al., 2011). Side effects of BFR are minimal with the use of appropriate methods of application and under the guidance of a trained practitioner (Brandner et al., 2018). The goal of this study was to compare the effects of 8 weeks of resistance exercise training with and without BFR on: 1) hemodynamics (e.g., blood pressure and resting heart rate); 2) arterial elasticity (e.g., pulse wave velocity); 3) muscular force production (e.g., maximal voluntary contraction, and estimated one-repetition maximum); 4) EMG (e.g., amplitude of maximal voluntary contraction); and 5) body composition (e.g., dual-energy X-ray absorptiometry, or DEXA) in males between the ages of 50 to 70 years of age.

Chapter II is a literature review of the aging population, BFR and resistance training, arterial compliance, neuromuscular function, and health and safety concerns. Chapter III

discusses the methodology. In Chapter IV, the results are presented. Chapter V interprets the findings, states the conclusion, and the future implications of the research.

CHAPTER II

REVIEW OF THE LITERATURE

The purpose of this study was to compare the effects of 8 weeks of resistance exercise training with and without BFR on: 1) hemodynamics (e.g., blood pressure and resting heart rate); 2) arterial elasticity (e.g., pulse wave velocity); 3) muscular force production (e.g., maximal voluntary contraction, and estimated one-repetition maximum); 4) EMG (e.g., amplitude of maximal voluntary contraction); and 5) body composition (e.g., dual-energy X-ray absorptiometry, or DEXA) in males between the ages of 50 to 70 years of age.

Fiscal Impact of Aging Population

Improvements in health outcomes have led to increases in longevity (Elo, 2009; US Department of Health and Human Services, 2018). By 2030, 20% of the population aged 65 and over will be at the retirement age (US Census Bureau, 2018). The population over age 65 is expected to almost double from 49.2 million in 2016 to 98 million in 2060 (US Department of Health and Human Services, 2018).

The ratio of older adults (65+ years) to working-age adults is known as the old-age dependency ratio and is the standard indicator of population aging (Spijker, 2020). This number compares the dependent elderly (aged 65 + years) to the working population (aged 16-64 years) who would pay for them. Current projections by the U.S. Census Bureau (2018) suggest that by 2060, there will be less than 2.5 working-age adults for every retirement-age person, a drop from

the 2020 estimation of 3.5 working-age adults for every retirement-age person. This ratio was developed over 100 years ago, does not take into account medical advancements delaying retirements for many older Americans, and can be argued to be outdated or obsolete (Gonzalez III et al., 2020; Sanderson & Scherbov, 2015). Regardless of obsolescence, this ratio does reveal that a reduced working population will incur the burden of a growing aging population. The old-age dependency ratio is projected to be about 41% in 2060, which is a dramatic increase from the average ratio of 25% in 2015; a one percent point increase in the ratio would decrease state revenue by $100 per person (Nartey, 2019). It was estimated that in 2012, the total value of informal care, which is care provided by a friend or family member, was between US$200 billion and US$600 billion (Chari et al., 2015). Assessing the fiscal impact of an aging population is beyond the scope of this study, but it is still important to recognize the impact it will have on the economy.

Subjective Cognitive Function

A subjective cognitive function assessment can be used as a predictor of future dementia. People who are active in early adulthood and in later life have the lowest odds of dementia. However, being active in either early adulthood or later in life were both independently associated with better social cognitive function in later life (Fondell et al., 2018). Studies have shown that exercise prevents cognitive decline associated with aging (Hötting & Röder, 2013; Niemann et al., 2014). Resistance training has a particularly pronounced effect on executive function, memory, and working memory (Gates et al., 2013; Northey et al., 2018).

The aging process is accompanied by a progressive decline in quantitative and qualitative dimensions of skeletal muscle known as sarcopenia (Trombetti et al., 2016). The reduction in skeletal muscle mass or skeletal muscle function (measured by assessing strength or

performance) can lead to reduced health outcomes and loss of physical independence (Dam et al., 2014; Studenski et al., 2014). Work done by Dos Santos et al. (2017) suggests that the loss of muscle function has a leading role in the relationship with muscle mass, as the loss of muscle function occurs faster and with greater magnitude. Resistance training seems to be the most effective in attenuating the loss of muscle strength and mass (Boengler et al., 2017; Iolascon et al., 2014). There is evidence that short-term resistance training can improve muscle function (Fragala et al., 2014).

Body Composition

Body composition is the relative amount of bone, lean tissue, and fat tissue that makes up the human body. Changes in body composition are common and varying throughout the lifespan, with a general decrease of lean tissue and an increase of central fat accumulation (Newman et al., 2005; Vlassopoulos et al., 2014). There are several ways to measure body composition in a laboratory: air displacement plethysmography, hydrodensitometry (underwater weighing), and dual-energy X-ray absorptiometry (DEXA).

The progressive skeletal muscle disorder involving the accelerated loss in muscle mass and muscle strength is known as sarcopenia (Cruz-Jentoft & Sayer, 2019). Skeletal muscle cross sectional area has been reported to decrease by 40% from the age of 20 yrs to 60 yrs (Doherty et al., 1993; Porter et al1995; Vandervoort, 2001), with an accelerated decline onwards from age 50 yrs (Lexell et al., 1988). Having an exercise routine during middle adulthood has been shown to be a protective factor against sarcopenia in older age (Akune et al., 2014). As little as 6 weeks of resistance training has been shown to induce skeletal muscle hypertrophy in untrained older males (Frontera et al., 1988). Osteoporosis is an age-related bone disorder that increases the risk of fracture due to low bone mineral density (BMD), impaired bone

microarchitecture/mineralization, and/or decreased bone strength (Kanis, 1990; Tu et al., 2018). Due to higher prevalence of osteoporosis in women compared to men, there is limited research on the effects of a resistance training program on bone mineral density in older males (Bolam et al., 2013; Kelley et al., 2013; Kemmler et al., 2018). One study examined the independent and combined effects of high intensity resistance training and fortified milk in men aged 50-79 years. The 12-month trial recruited 180 men and demonstrated a 1.5% improvement in lumbar spine bone mineral density (Kukuljan et al., 2009). The research on improving bone mineral density in older males may be inconclusive, but there seems to be a consensus that resistance training will at least maintain bone mineral density in older males (Bolam et al., 2013; Whiteford et al., 2010).

Blood Flow Restriction Training

Sometimes known as KAATSU (the Japanese word for "pressurization" or "additional pressure") training, blood flow restriction training (BFR) was pioneered in Japan by Yoshiaki Sato more than 50 years ago (Sato, 2005). This method, whereby applying inflatable cuffs to the proximal portion of the working limbs, has been shown to produce the hypertrophic response typically seen following resistance training programs working at intensities greater than 70% of a one-repetition maximum (Lixandrão et al., 2018; Takarada, Takazawa, et al., 2000). There were some safety concerns regarding BFR such as impairments to nerve conduction velocity or post-exercise blood flow (Loenneke et al., 2011), but the growing body of evidence suggests that it is a relatively safe technique to use with resistance training (L. Hughes et al., 2017; Jessee et al., 2018; Slysz et al., 2016).

Mechanical tension and metabolic stress are the drivers of muscle hypertrophy, so it stands that BFR would have both. The low level of mechanical tension implies that metabolic

stress is the primary driver of muscle hypertrophy during BFR. The metabolic stress creates a cascading effect toward muscle growth by elevating systemic hormone production (Reeves et al., 2006; Takarada, Nakamura, et al., 2000), cell swelling (Loenneke, Fahs, et al., 2012), intramuscular anabolic signaling (Fry et al., 2010; Laurentino et al., 2012), increasing production of reactive oxygen species (Kawada & Ishii, 2005), and increasing type 2 muscle fiber recruitment (Yasuda et al., 2009). Some of the theorized mechanisms are primarily driven by mechanical tension, which brings to question their involvement with muscle growth from BFR (Pearson & Hussain, 2015).

The American College of Sports Medicine recommends moderate-to-high-intensity resistance exercise and high-impact exercises to stimulate bone growth, or in the case of the elderly, to maintain it (American College of Sports Medicine, 2009; Bittar et al., 2018). Recommendations are not always feasible; In many older patients, the presence of other pathologies (e.g., cardiovascular disease) discourages the programming of high-intensity or high-impact exercises (Papa et al., 2017). The low-intensity nature of BFR training would suggest that bone adaptations would not occur, but some studies suggest otherwise. Studies by Bemben (2007) and Karabulut (2011) measured bone markers following BFR training. The former found that bone resorption markers increased significantly following an acute bout of BFR training; the latter had similar findings following a short-term BFR training (Bemben et al., 2007; Karabulut et al., 2011).

Regardless of the primary stimulus, BFR is an ideal training method for populations that cannot tolerate heavy resistance training, which is characterized by high mechanical stress and high forces placed on the joints (L. Hughes et al., 2017). BFR can attenuate strength loss or facilitate strength recovery in clinical populations following an injury (DePhillipo et al., 2018;

Gorgey et al., 2016; L. Hughes et al., 2018). BFR does not seem to increase exercise-induced pain (Segal, Davis, et al., 2015; Segal, Williams, et al., 2015).

The body of research on BFR shows that it is an excellent accessory to exercise training, regardless of mode. However, a majority of the research has been conducted on young adults. Evidence is still sparse on how BFR affects older adults.

Arterial Compliance

Arterial compliance is an index reflecting the ability of the arteries to absorb changes in blood pressure and blood flow (Arnett et al., 1994; Tanaka & Safar, 2005). The loss of elasticity is a characteristic of the aging process. (Lund-Johansen, 1988; McVeigh et al., 1999; Tanaka & Safar, 2005). The reduction of arterial compliance is associated with several age-related pathologies such as hypertension, left ventricular hypertrophy, and congestive heart failure (Laurent et al., 2005; Demer & Tintut, 2008). Arterial compliance is an independent risk factor for future cardiovascular disease (Hirai T et al., 1989; Sloten et al., 2014).

The effect of exercise on arterial compliance is largely based on modality. Resistance training, especially at high intensities, has shown to increase arterial stiffness (Miyachi et al., 2004; Ozaki et al., 2013; Tagawa et al., 2018). Resistance Training at a moderate intensity seems to have neither a positive nor negative on arterial compliance in older men (Cortez-Cooper et al., 2008; Maeda et al., 2006). One might consider that maintaining arterial compliance at an older age may be a positive effect of the resistance training. A study on young males performing either “heavier load and lower repetitions" or “lighter load and higher repetitions" found that neither resistance training protocol improved arterial compliance (Au et al., 2017). Aerobic exercise training has shown to improve arterial compliance (J. N. Cook et al., 2006; Fujie et al., 2016;

Kim et al., 2017), regardless of intensity or duration (Kobayashi et al., 2020). The combination of aerobic and resistance training seems to attenuate the arterial stiffness associated with resistance training alone (Kosaki et al., 2019; Otsuki et al., 2020; Wong et al., 2018). Shiostu et al. (2018) posits combining aerobic and resistance training with aerobic training preceding resistance training could favorably affect arterial stiffness.

Neuromuscular Function

The age-related weakness which is often credited to the decline in lean body mass is a condition known as sarcopenia (Evans, 1995). Several longitudinal studies have shown a disassociation between muscle mass and muscle strength (V. A. Hughes et al., 2001; Newman et al., 2006; Visser et al., 2005). This suggests that age-related weakness is much more complex and physiological adaptations may mediate age-related weakness.

Electromyography (EMG) is a technique that is used for evaluating maximal volitional activation of a muscle. Surface EMG (sEMG) places a pair of electrodes on the skin over the belly of the muscle of interest and a record is taken of the net electrical activity of the motor neuron and muscle fibers within the detection area (Clark & Fielding, 2012). A variety of factors may impact the recording and interpretation of sEMG, such as the placement of the electrode relative to the muscle fibers, the amount of subcutaneous adipose tissue between the electrode and the muscle, and asynchronous firing of action potentials (De Luca, 1997). Normalizing the sEMG amplitude to a reference contraction (e.g., maximal voluntary contraction) can reduce the error associated with previously stated factors (Burden & Bartlett, 1999).

Previous studies in older populations have shown that resistance training can improve muscle mass and muscle function (Borde et al., 2015; Kirk et al., 2020; Peterson et al., 2010;

Turpela et al., 2017). However, the effect of resistance training on structural change is not as pronounced (Stewart et al., 2014). Therefore, any short-term strength improvements will likely be neural adaptations and not muscle hypertrophy (Delmonico et al., 2009; Frontera, 2000)..

Investigations on the effect of BFR training on neuronal adaptations in older populations are sparse and any conclusions made with the limited research would be hasty. The findings from research on young and healthy populations can be insightful with some caution. For example, in younger populations, EMG amplitude was greater following heavy-load resistance training than BFR training with lower loads (S. Cook et al., 2013; Kubo et al., 2006; Manini & Clark, 2009). However, this may be different in older populations due to changes in atrophy of fast-twitch muscle fibers and differences in motor unit firing statistics (Yamada et al., 2002). The present study hopes to improve the knowledge body of neuromuscular adaptations in middle adulthood following resistance training.

Conclusion

Chapter III contains a discussion of the methodology used to conduct the present study. In chapter IV, the results of the study are presented and discussed. Chapter V contains a summary of the study, conclusions and recommendations for future research related to beginner training programs.

CHAPTER III

METHODS

The purpose of this study was to compare the effects of 8 weeks of resistance exercise training with and without BFR on: 1) arterial elasticity and hemodynamics (e.g., blood pressure and resting heart rate), 2) muscular force production (e.g., maximal voluntary contraction, force production, electromyography, and estimated one-repetition maximum) in males between the ages of 50 to 70 years of age.

Subjects

A total of 46 participants were screened for the current study. Of those, 43 met the inclusion criteria, and 31 completed the study. All participants read and signed an informed consent prior to any testing or training. Participation was completely voluntary and withdrawing from the study was allowed at any time without consequence. This study was approved by the University of Texas Rio Grande Valley Institutional Review Board.

Inclusion Criteria

1. Participants who were within 50 to 70 years of age;
2. Participants with no diagnosed hypertension, cardiovascular disease, a recent musculoskeletal injury; and
3. Participants who did not require a medical clearance to participate in resistance exercise training.

Exclusion Criteria

1. Participants who were outside the 50-70 years age range.
2. Participants who were taking any medication for diagnosed hypertension, cardiovascular disease, metabolic disease, or chronic pain.
3. Participants with an acute history of musculoskeletal injury.
4. Participants requiring medical clearance to participate in resistance exercise.

Recruitment

Participants were primarily recruited via community outreach in Brownsville, Texas. Participants were also recruited using fliers at the University of Texas – Rio Grande Valley as well as word of mouth. Participation was voluntary and withdrawal from the study was allowed at any time. Interested participants were given an informal, pre-screening interview via a telephone call or text message. This was used to rule out any participants who would have not met the inclusion criteria and save their time. The informal interview began with a brief introduction of the researcher. Then, an introduction and purpose of the study, as well as volunteer expectations. Once a verbal agreement was made between the potential volunteer and the researcher, the participant was then scheduled and given instructions on how to dress and prepare for their testing sessions. A reminder text was sent to them the night before their scheduled visit.

Experimental Protocol

All testing procedures were conducted in the Neuromuscular Performance Lab (Vocational Trade Shops, room 216, Brownsville, TX), the Body Composition Room (Cortez Hall, room 214, Brownsville, TX), and the Training Room, (Cortez Hall, room 220, Brownsville,

TX). The participant and researcher agreed on time schedules that were most convenient to the participant so that he was both fasted (for at least 8 hours) and hydrated. Hydration was monitored with the use of a urine refractometer, which required a urine sample from the participant to determine the level of current hydration. A participant was deemed “well hydrated” when the refractometer gave a reading below 1.010 (Casa et al., 2000).

Baseline testing was conducted over two days, with a 48-hour period separating them. On the first day, the participants filled out a health history form, a physical activity readiness questionnaire (PAR-Q), and an informed consent. They were then familiarized with the study procedures before starting the exercise sessions. Participants who answered yes to any PAR-Q question or had blood pressure equal to or higher than 150/90 mmHg were excluded from participation. The subjects were instructed to lie supine on an examination table for 5 minutes. After the 5 minutes passed, heart rate, blood pressure, and central pulse wave velocity were recorded. The data was collected using an applanation tonometry device by SphygmoCor Xcel (AtCor Medical Pty. Ltd., Sydney, Australia) which has been validated and highly reliable (Hwang et al., 2014). Peripheral pulse wave velocity was recorded using SphygmoCor (AtCor Medical Pty. Ltd., Sydney, Australia) which has been thoroughly tested and validated (Pauca et al., 2001; Adji et al., 2007). Weight and body fat percentage were measured via two methods: dual-energy x-ray absorptiometry using the GE Lunar iDXA (GE Lunar Prodigy, enCORE software version 6.70.021; GE Healthcare, Madison WI) system and bioelectrical impedance. The iDXA system has been well validated and acceptable for use when assessing body composition changes (Haarbo et al., 1991; Rothney et al., 2012).

The second day of testing was conducted in the Training Room (Cortez Hall, room 214, Brownsville, TX). A 5-repetition maximum test was conducted on the five exercise machines, in

order: leg press, chest press, leg extension, shoulder press, and leg curl. The test began with a warm-up set of 10 repetitions, followed by an increase in weight of 5-10% for upper body exercises or 10-20% for lower body exercises. Additionally, the Borg Rating of Perceived Exertion (RPE) scale was used to assess perceived exertion between trials. The test was terminated after the participant reported an RPE greater than 18, or if they could not complete the 5 repetitions. A rest period of 1-5 minutes was given between trials, dependent upon their reported RPE. A second repetition maximum test was performed at the midway point of their training.

The eight weeks following the baseline data collection period were the actual training sessions in which the participants performed their specified exercise routine 3 times a week, at the same time each day, unless a scheduling conflict forced a change. Each session was separated by 48 hours. The five machine-based exercises selected for the training study were: leg press, leg extension, leg curl, incline chest press, and shoulder press.

The research team calibrated all the equipment according to manufacturer specifications prior to any testing. The research team also knew how to properly use all the equipment and had all the documentation in order to conduct research.

The participants were randomly assigned to one of three groups:

The Blood Flow restriction group had BFR cuffs applied to the arms first (for upper body exercises) and then the legs (for lower body exercises), raised to the desired pressure in accordance with laboratory protocol. The participants rested at least 30 seconds between each set. Their exercise program consisted of 4 sets of 20 repetitions per exercise at 20-30% of their estimated one-repetition maximum. The participants began the training at 20% and increased as

time progressed. There was a rest period of at least 3 minutes between upper body and lower body exercises.

The endurance resistance training group was assigned an exercise program consisting of 4 sets of 15 repetitions with each of the exercises performed at 40-65% of their estimated one-repetition maximum. The participants were started at the lower end of the range, and as their time progressed through the study, the intensity was increased. Rest periods between sets were 60 seconds initially and reduced over time to 30 seconds. This was dependent on their performance and RPE.

The control group performed no exercise throughout the 8-week intervention period. They only visited the lab for pre- and post-test values and continued with their normal daily activities. They were instructed to maintain the same lifestyle, keeping their daily routines, and not adjust dietary intake or adopt an exercise routine.

Each training session was preceded by a 5-minute walk or jog at a self-selected speed. The participants were also given the option to perform a 5-minute cool down following each training session. Drinking water and towels were provided to the participants during their training sessions. The exercise machines were cleaned and wiped down frequently with sanitizer spray between participants.

The week following the completion of the training program consisted of measuring all variables that were recorded in week 1 in the same order, and 48 hours apart. Participants were again instructed to be fasted and hydrated. Participants were also asked to wear the same clothing or clothing very similar to what they wore during their first visit. This was to control any chance for variability during the body composition tests.

Participation in this study was not without minimal risk. The one-repetition maximum tests and testing on the Biodex can both cause fatigue and muscle soreness following testing. The use of BFR cuffs can and sometimes did cause discomfort during and after use. The participants were allowed to stop participation momentarily or withdraw completely at any time.

Instruments

Clinical Urine Refractometer

Participants were required to provide a urine sample prior to the testing sessions. Hydration was assessed by placing a sample size no bigger than 2-3 drops onto the lens of the urine refractometer (PAL-10S Urine Specific Gravity Refractometer, Atago, Tokyo, Japan). Using an internal light, the device analyzed the sample and results were displayed almost instantly. Accepted urine specific gravity results were below 1.010. Any sample that resulted above was rejected and the participant was recommended to drink water or to reschedule. The analyzed sample was then returned to the sample cup and placed into the biohazard waste disposal. The device was cleaned according to manufacturer specifications.

Dual Frequency Total Body Composition Analyzer

Bioelectrical impedance analysis (BIA) is a method of measuring body composition. The participants were asked to remove their socks, stand on the platform of the analyzer (DC-430U Dual Frequency Total Body Composition Analyzer, Tanita, Tokyo, Japan), and have basic information (e.g., height and age) entered into the control box of the analyzer. After about 20 seconds, body composition assessment was complete.

Pulse Wave Velocity

Pulse wave velocity (PWV) is a measure of arterial stiffness, which is the rate at which pressure waves travel down the blood vessels. For this study, PWV was measured centrally (i.e., around the heart), and systemically (i.e., in the arms and legs) using applanation tonometry

(Sphygmocor XCEL, Atcor Medical Pty. Ltd., Sydney, Australia). To measure PWV centrally, the participants lied on the examination table in a supine position. A blood pressure cuff was placed around the thigh. The distances between the top edge of the cuff and the suprasternal notch, the carotid pulse site and the suprasternal notch, and the top of the cuff to the femoral pulse site were measured and input into the computer for analysis. The tip of the tonometer was placed on the carotid pulse on the neck; once the pulse was detected, the femoral cuff would inflate, and a recording was complete in less than 20 seconds. For systemic PWV, three electrodes were placed on the chest of the participants: at the top and bottom end of the sternum and on the rib cage along the mid-axillary line. Segmental measurements were taken from the suprasternal notch to the carotid, radial, femoral, and posterior tibial pulse sites. The tip of the tonometer was placed on each one of these pulse sites and a recording was taken.

Lunar iDXA

Dual-energy X-ray absorptiometry uses very low-grade x-rays to measure bone mineral density and body composition. Subjects were instructed to remove their shoes and any metallic objects (e.g., jewelry) and to lie supine on the iDXA (GE Lunar Prodigy, enCORE software version 6.70.021; GE Healthcare, Madison WI) bed. The robotic arm of the iDXA scanned the participants from head to toe in about 5-10 minutes. Results of the scan were available immediately.

Delsys Electromyography

Delsys Trigno wireless system (Delsys Inc., Boston, MA, USA) was used to measure the electrical activity in the muscle tissue, otherwise known as electromyography (EMG). The surface EMG (sEMG) sensors were rectangular in shape and measured 27 mm x 37 mm x 13 mm in size. Each sEMG contains two pairs of electrodes spaced 10 mm apart. Three sEMG sensors were placed on the right quadriceps of the participants: one over the belly of the vastus

lateralis, one over the belly of the rectus femoris, and one over the bell of the vastus medialis. The location of the belly of the vastus lateralis was calculated by taking 66% of the length starting at the anterior superior spine of the iliac crest and ending at the lateral side of the patella. The belly of the rectus femoris was estimated to be 50% of the length starting at the anterior superior iliac spine and ending at the superior part of the patella. The belly of the vastus medialis was estimated to be located at 80% of the length from the anterior superior iliac spine to the joint space in front of the anterior border of the medial ligament was where the belly of the vastus medialis was (Hermens et al., 1999). The area where the sensor was placed was shaved and then cleaned with an alcohol swab to ensure proper adhesion. EMGworks Acquisition and Analysis software (Delsys Inc., Boston, MA, USA) was used to capture and analyze the raw data collected from the EMG electrodes. Filtering of the raw EMG was done by using a modified bandpass Butterworth filter at 5-5000 Hz.

Biodex Multi-Joint System – Pro

The Biodex Multi-Joint System – Pro is an isokinetic dynamometer that is used to assess muscle function both dynamically and in a static position. It can provide mechanically reliable measures of torque and velocity. Participants were seated on the Biodex. Straps were placed over the trunk of their body, over the untested left leg, and their right leg was strapped into a lever arm of the dynamometer. Depending on the tests, participants were then instructed to perform maximal-effort contractions with a controlled speed or in a static position to measure torque or force production, respectively. A rest period of at least 3 minutes was given between tests.

Blood Flow Restriction (BFR) Cuff

Elastic cuffs (KAATSU Global, Sato Sports Plaza Ltd., Tokyo, Japan) were used to modulate blood flow. They were 50 mm in width. They were connected to a pneumatic machine that controlled the inflation, and thereby pressure of the cuffs. Depending on the exercise, the

cuffs were placed at the uppermost portion of the appendages and inflated to an initial pressure or tightness of 120 mmHg. Using an interval of 30 seconds of pressure to 10 seconds of relaxation, the cuff pressure was increased in increments of 20 mmHg until the final pressure was reached. The final pressure was achieved when capillary refill time was between 2 and 3 seconds (KAATSU Global, 2017).

Statistical Analysis

One-way ANOVA was used to test baseline differences between groups. A two-way analysis of variance (ANOVA) with repeated measures (condition (BFR vs. END vs. CON) x time (pre vs. post)) was used to determine whether there were any significant differences between groups before and after the training program and homogeneity of variances was confirmed by Levene's test. A Bonferroni correction was used if a significant difference was found. Even though no statistical differences between group means for most variables were detected at baseline, there were large differences in group means for several variables tested. Therefore, analysis of covariance (ANCOVA) was also used to account for differences and compare groups from pre- to post-training for those particular variables with large differences in group means. Results from both ANOVA and ANCOVA were reported for each variable tested. All data were expressed as means ± SE in the text, figures, and tables. An alpha of $p \leq 0.05$ was used to determine significance. Data was analyzed using SPSS for Windows (IBM Corporation, New York, USA).

CHAPTER IV

RESULTS

The purpose of this study was to compare the effects of 8 weeks of resistance exercise training with and without BFR on: 1) hemodynamics (e.g., blood pressure and resting heart rate); 2) arterial elasticity (e.g., pulse wave velocity); 3) muscular force production (e.g., maximal voluntary contraction, and estimated one-repetition maximum); 4) EMG (e.g., amplitude of maximal voluntary contraction); and 5) body composition (e.g., dual-energy X-ray absorptiometry, or DXA) in males between the ages of 50 to 70 years of age.

Subject Characteristics

A total of 43 male participants were recruited to participate in the study. Of the total, 31 completed the study. These participants were recruited from the community and through recruitment campaigns at The University of Texas Rio Grande Valley in Brownsville, Tx.

Table 1. Descriptive Measures

Variables	**Blood Flow Restriction**	**Endurance**	**Control**
	(n = 10)	**(n=11)**	**(n=10)**
Age (yr)	56.2 ± 1.18	57.90 ± 1.49	56.70 ± 1.40
Height (cm)	174.66 ± 1.60	173.19 ± 1.9	174.32 ± 1.74
Weight (kg)	93.5 ±3.19	92.50 ± 5.20	84.07 ± 2.6
Body Fat (%)	35.54 ± 1.60	34.87 ±1.37	32.79 ± 1.06

Hemodynamic Responses

Table 2 shows the effects on hemodynamic responses after 8 weeks of training. Significant baseline differences were detected in the following variables: aortic systolic blood pressure, aortic mean arterial pressure, systemic systolic blood pressure, and systemic mean arterial pressure. No other baselines differences between groups were detected and homogeneity of variances was confirmed by Levene’s test. A significant time main effect was seen in mean arterial pressure ($p < 0.05$). Significant time main effects were also seen for the following categories: systemic systolic blood pressure, systemic diastolic blood pressure, mean arterial pressure in systole, and mean arterial pressure in diastole ($p < 0.05$). All other categories were not statistically different for condition and time main effects and interactions.

Figure 1 shows the change in aortic mean arterial pressure (MAP). One-Way ANOVA found significant baseline differences. Levene’s test confirmed homogeneity of variance. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found a significant time main effect ($p < 0.05$). No other conditions and main effects or interactions were seen.

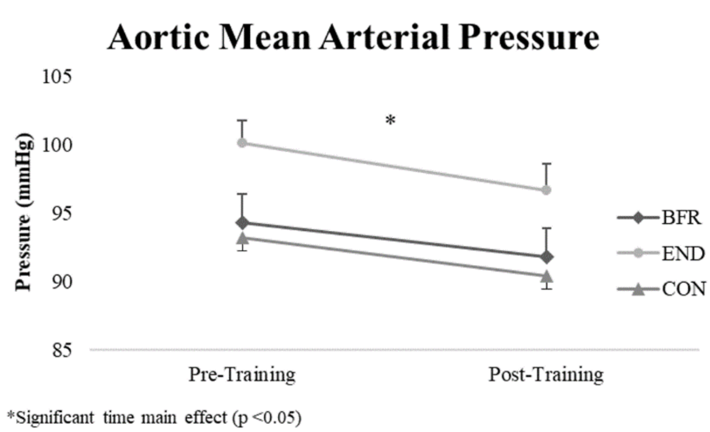


Figure 1. Aortic Mean Arterial Pressure

Table 2. Hemodynamic Responses

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Aortic Systolic Blood Pressure (mmHg)	119.3 ± 2.03	115.7 ± 2.62	125.54 ± 2.20	122.27 ± 2.67	116.4 ± 2.03	114 ± 3.17
Aortic Diastolic Blood Pressure (mmHg)	79.9 ± 2.23	77.7 ± 1.86	125.55 ± 2.20	122.27 ± 2.67	116.40 ± 2.03	114.00 ± 3.17
Aortic Pulse Pressure (mmHg)	39.40 ± 1.65	38.00 ± 1.71	85.00 ± 1.94	81.64 ± 1.76	79.40 ± 1.13	76.20 ± 1.12
Mean Arterial Pressure (mmHg)	**94.3 ± 2.06**	**91.8 ± 2.06**	**100.09 ± 1.66**	**96.64 ± 1.96**	**93.20 ± 1.06**	**90.40 ± 1.60**
Systemic SBP (mmHg)	**129.8 ± 1.95**	**126.2 ± 3.01**	**135.91 ± 2.83**	**131.73 ± 3.20**	**126.00 ± 2.01**	**122.60 ± 3.19**
Systemic DBP (mmHg)	**78.8 ± 2.17**	**77.3 ± 1.89**	**84.09 ± 1.89**	**80.55 ± 1.74**	**78.30 ± 1.27**	**74.30 ± 1.27**
Peripheral Pulse Pressure (mmHg)	51 ± 1.56	49 ± 2.53	52.27 ± 3.21	51.18 ± 2.64	47.10 ± 2.62	47.70 ± 2.42
Heart Rate (bpm)	61.0 ± 2.13	63.4 ± 2.61	63.09 ± 1.44	60.91 ± 1.83	63.20 ± 1.78	64.30 ± 2.49
Pulse Period (ms)	992.4 ± 35.19	961.8 ± 39.46	956.64 ± 23.06	992.27 ± 28.22	954.60 ± 32.47	944.80 ± 32.47
Ejection Duration (ms)	341.6 ± 5.09	337.3 ± 7.12	339.73 ± 6.50	345.64 ± 5.73	336.30 ± 4.60	335.70 ± 6.55
T2 (ms)	223.5 ± 3.49	220.9 ± 4.19	230.09 ± 3.20	241.91 ± 12.15	225.90 ± 3.68	227.50 ± 3.55
P1 Height (mmHg)	31.1 ± 0.92	29.8 ± 1.60	31.36 ± 1.93	31.36 ± 1.97	28.10 ± 1.66	28.40 ± 1.68
Aortic Augmentation (mmHg)	10.8 ± 1.62	10.3 ± 0.92	12.36 ± 1.25	12.27 ± 1.08	11.80 ± 1.34	12.60 ± 1.40
Aortic Augmentation index AP/PP (%)	0.263 ± .0.03	0.27 ± 0.03	0.30 ± 0.03	0.31 ± 0.03	0.31 ± 0.02	0.33 ± 0.02
Aortic Augmentation index P2/P1 (%)	1.285 ± 0.03	1.291 ± 0.03	1.31 ± 0.03	1.32 ± 0.03	1.33 ± 0.02	1.35 ± 0.02
Aortic Augmentation index @Hr75 (%)	0.198 ± .0.03	0.215 ± 0.03	0.25 ± 0.02	0.24 ± 0.03	0.25 ±0.02	0.28 ± 0.03
Buckberg Subendocardial viability ratio (%)	1.52 ± 0.08	1.48 ± 0.07	1.47 ± 0.06	1.49 ± 0.04	1.49 ± 0.06	1.46 ± 0.05
Pressure Time Index - Systole (mmHg*s/m)	2262.9 ± 74.39	2228.0 ± 65.12	2448.91 ± 72.09	2332.82 ± 72.32	2251.60 ± 55.47	2217.90 ± 52.13
Pressure Time Index - Diastole (mmHg*s/m)	3393.6 ± 112.38	3277.5 ± 111.26	3556.00 ± 85.46	3455.91 ± 61.82	3337.60 ± 71.25	3212.10 ± 85.43
End Systolic Pressure (mmHg)	107 ± 2.81	103.6 ± 2.93	113.73 ± 1.89	110.45 ± 2.17	106.2 ± 2.20	103.70 ± 2.80
Mean Arterial Pressure in Systole (mmHg)	**108.6 ± 1.99**	**105.3 ± 2.37**	**114.55 ± 1.84**	**111.09 ± 2.36**	**106.30 ± 1.52**	**103.60 ± 2.66**
Mean Arterial Pressure in Diastole (mmHg)	**86.8 ± 2.24**	**84.6 ± 2.05**	**92.00 ± 1.82**	**88.82 ± 1.84**	**86.10 ± 1.22**	**83.50±1.35**

Values reported as mean ± SE
Bold and underlined data indicates a significant time main effect ($p < 0.05$)

Figure 2 shows change in systemic systolic blood pressure following 8 weeks of resistance training. Baseline differences were detected by one-way ANOVA. Homogeneity of

variance was confirmed by Levene's test. ANCOVA found no significant differences between groups. A significant time main effect ($p < 0.05$) was seen. No significant condition main effect or interactions were seen.

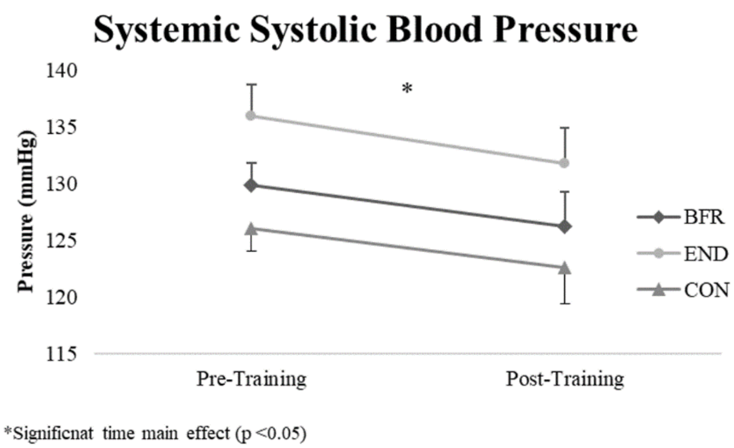


Figure 2. Systemic Systolic Blood Pressure

Figure 3 shows the changes in systemic diastolic blood pressure following 8 weeks of resistance training or control. No baseline differences were found and homogeneity of variances was confirmed by Levine's test. Two-way ANOVA with repeated measures found a significant time main effect ($p < 0.05$). No other main effects or interactions were seen.

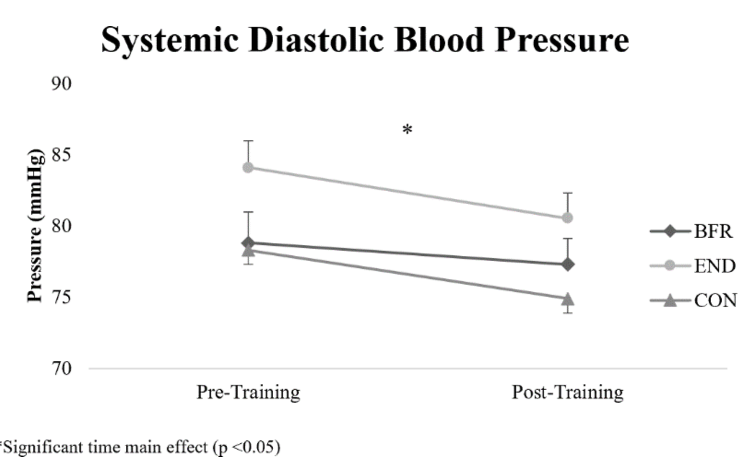


Figure 3. Systemic Diastolic Blood Pressure

Figure 4 shows the changes in mean arterial pressure (MAP) during systole. No significant baseline differences were found. Homogeneity of variances was confirmed by Levine's test. ANCOVA found no significant differences between groups. ANOVA showed a significant time main effect ($p < 0.05$). The time main effect showed a significant decrease in MAP during systole over time. No condition differences or condition*time interactions were observed.

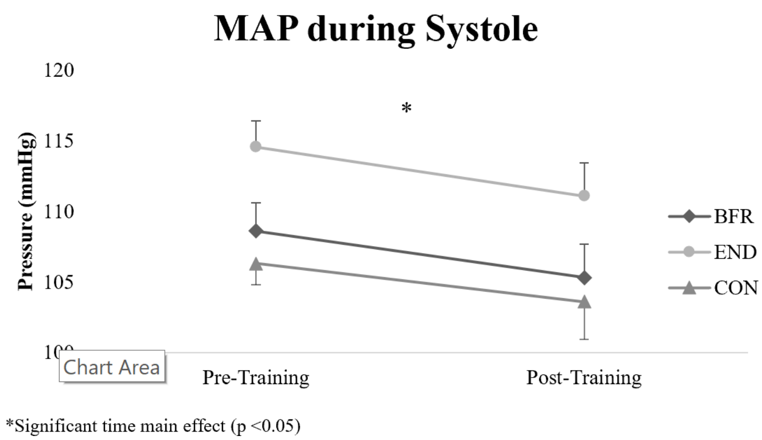


Figure 4. MAP during Systole

Figure 5 shows the changes in MAP during diastole. No significant differences were found at baseline. Levine's test confirmed homogeneity of variance. ANCOVA found no significant difference between groups. Two-way repeated measures of ANOVA showed a significant time main effect ($p < 0.05$), however there was no condition differences or condition*time interactions.

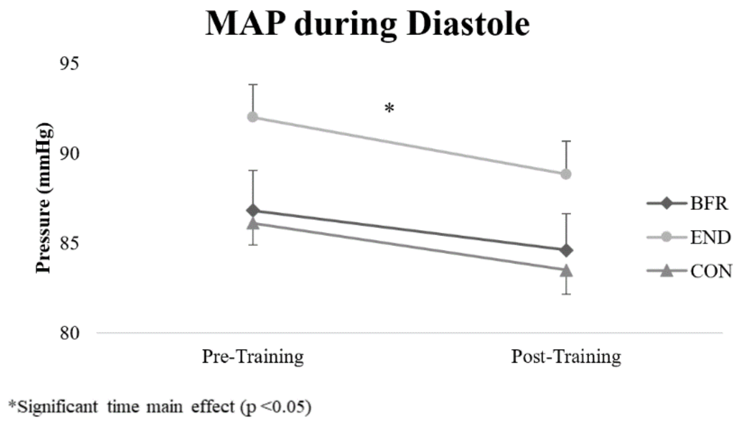


Figure 5. MAP during Diastole

Arterial Compliance

Table 3 shows the changes in arterial compliance within the three groups. No significant baseline differences were found, and homogeneity of variances was confirmed by Levine's test for all the variables listed. ANCOVA detected a significant difference between BFR and END groups ($p < 0.05$). Decreases in reflection magnitude were observed following BFR training, but there were increases in reflection magnitude following endurance resistance training.

Table 3. Pulse Wave Velocity

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Carotid to Radial Pulse Wave Velocity (m/s)	8.57 ± 0.43	8.28 ± 0.35	8.90 ± 0.43	8.09 ± 0.26	8.63 ± 0.32	8.80 ± 0.31
Carotid to Femoral Pulse Wave Velocity (m/s)	7.46 ± 0.34	7.51 ± 0.33	7.87 ± 0.17	7.84 ± 0.31	7.64 ± 0.33	7.99 ± 0.43
Femoral to Distal Pulse Wave Velocity (m/s)	9.36 ± 0.43	9.31 ± 0.30	9.98 ± 0.60	9.81 ± 0.37	10.64 ± 0.69	9.64 ± 0.45
Central Pulse Wave Velocity (m/s)	8.24 ± 0.34	8.03 ± 0.34	8.73 ± 0.31	8.29 ± 0.15	8.42 ± 0.29	8.52 ± 0.36
Forward Reflection	26.20 ± 1.36	26.40 ± 1.75	27.45 ± 1.72	24.36 ± 1.17	24.90 ± 1.18	25.10 ± 1.48
Backward Reflection	16.3 ± 0.97	15.7 ± 0.67	18.00 ± 0.89	17.73 ± 0.74	16.10 ± 1.06	16.30 ± 1.00
Reflection Magnitude	**0.629 ± 0.04**	**0.61 ± 0.03**	**0.67 ± 0.03**	**0.72 ± 0.03**	0.64 ± 0.02	0.65 ± 0.02
Pulse Transit Time	59.00 ± 1.98	58.9 ± 2.65	53.27 ± 2.13	58.27 ± 1.10	56.00 ± 1.87	55.80 ± 2.30

Values are reported as means ± SE
Bold and Underlined data a significant difference was seen between BFR and END groups ($p < 0.05$)

Figure 6 shows the change in central pulse wave velocity from pre- to post-training. No baseline differences were detected by one-way ANOVA. ANCOVA found no significant difference between groups. Two-way ANOVA with repeated measures detected no significant time main effects or condition*time interactions for pulse wave velocity.

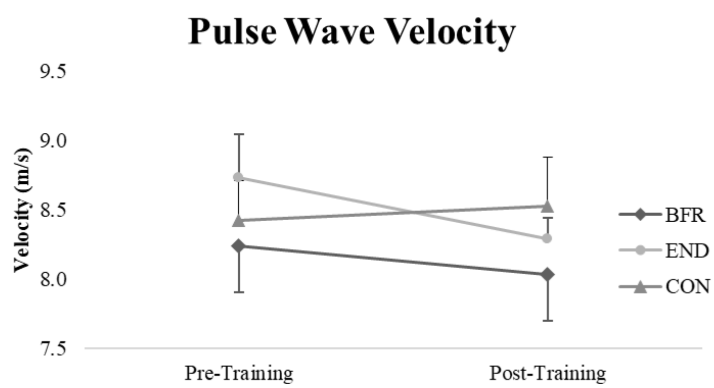


Figure 6. Central Pulse Wave Velocity

Figure 7 shows the change in the carotid-to-radial pulse wave velocity. No baseline differences were detected by one-way ANOVA. ANCOVA did not find any significant differences in carotid-radial PWV between groups. The categories were not statistically different for all condition and time main effects and condition*time interactions.

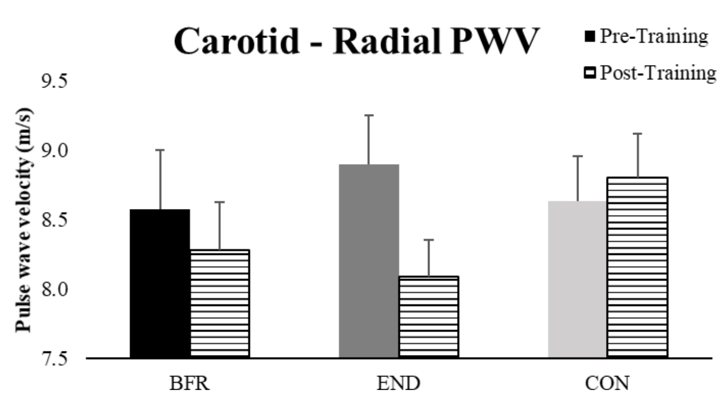


Figure 7. Carotid to Radial Pulse Wave Velocity

Figure 8 shows the change in the carotid-to-femoral pulse wave velocity. No baseline differences were detected by one-way ANOVA. ANCOVA found no significant difference between the groups. Two-way ANOVA with repeated measures time main effects or condition*time interactions.

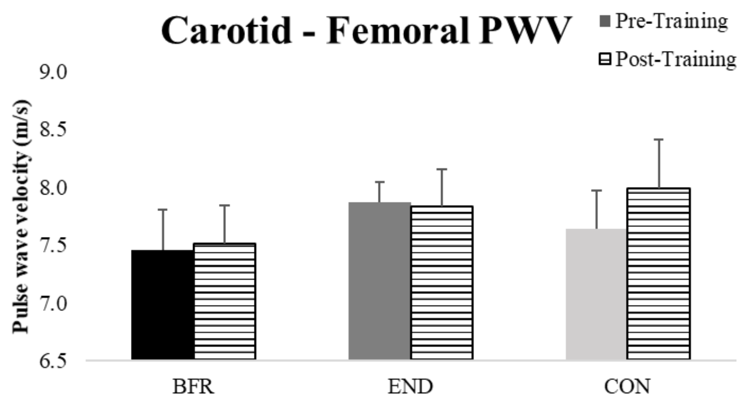


Figure 8. Carotid to Femoral Pulse Wave Velocity

Figure 9 shows the change in the femoral-to-posterior tibial pulse wave velocity. No significant baseline differences were found. ANCOVA found no significant differences between groups. No time main effects or condition*time interactions were detected by 2-way ANOVA with repeated measures.

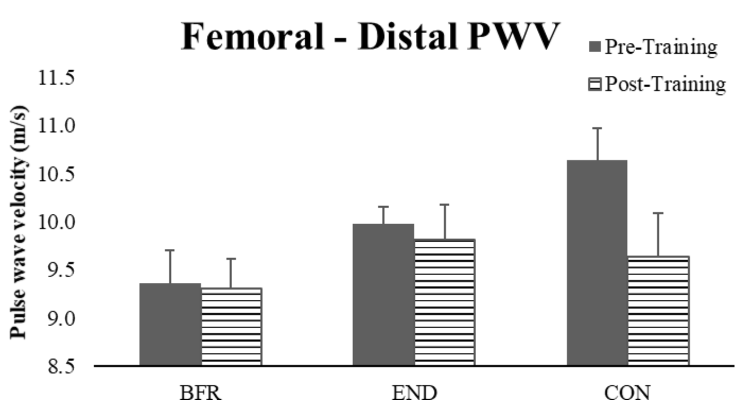


Figure 9. Carotid to Femoral Pulse Wave Velocity

Figure 10 shows the changes in reflection magnitude following 8 weeks of resistance training or a control. No baseline differences were detected by one-way ANOVA. Statistical analysis found that reflection magnitude for the BFR group was significantly reduced after the treatment compared to the END group ($p < 0.05$). Two-way ANOVA with repeated measures found no main effects or interactions.

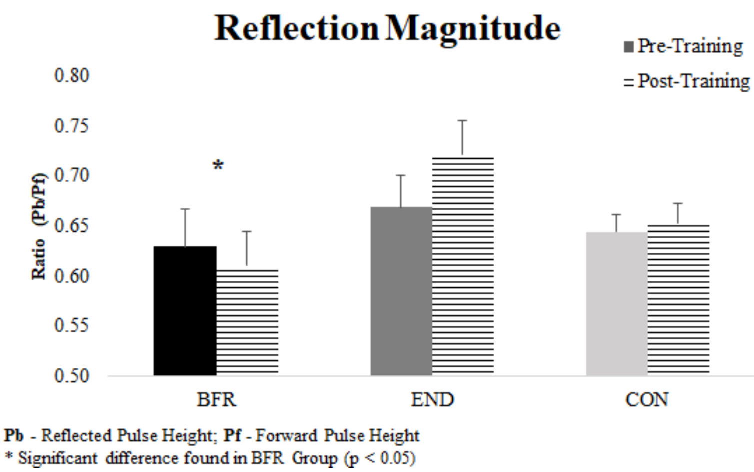


Figure 10. Reflection Magnitude

Strength Measures

Strength was measured in two ways: a one-repetition maximum (1RM) test and a unilateral knee extension test that measured torque at various speeds. The 1RM tests all showed significant time main effects. There was a condition*time interaction for the leg press, leg extension and leg curl 1RMs ($p < 0.05$). Three participants (two BFR and one control) did not return to complete the 1RM test; therefore, n=8 (instead of 10) in the BFR condition, and n=9 (instead of 10) in the CON condition.

Figure 11 shows the change in 1RM for the leg press following 8 weeks of resistance training. Figure 12 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were found. ANCOVA found

no significant differences between groups. ANOVA found a significant condition difference and a condition*time interaction for both BFR and END compared to the control group ($p < 0.05$).

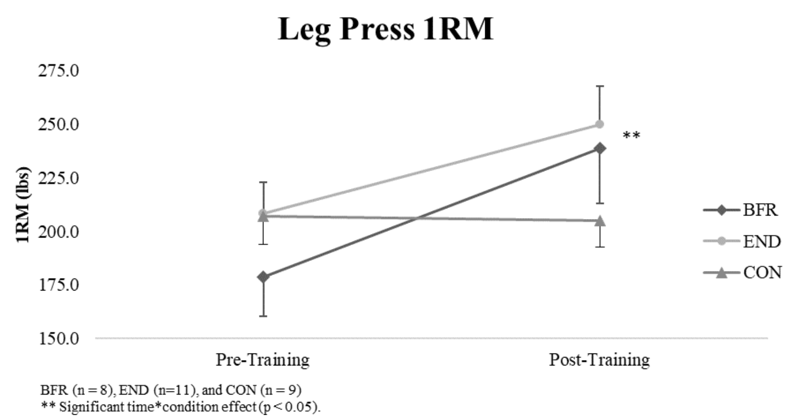


Figure 11. Leg Press 1RM

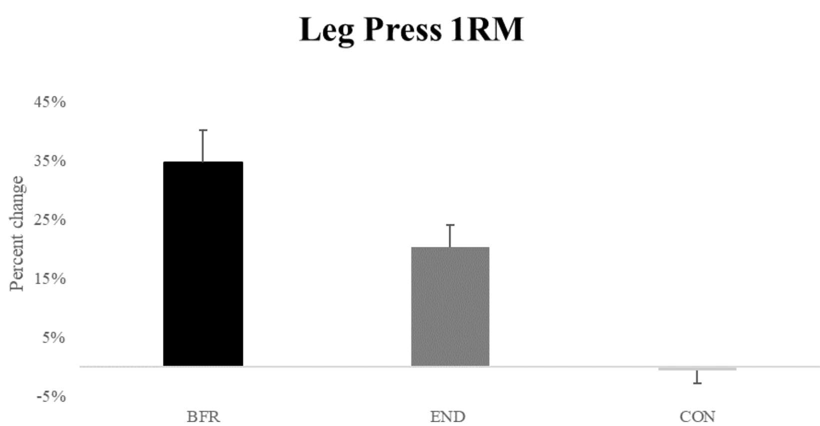


Figure 12. Leg Press 1RM percent change (% Change)

Figure 13 shows the change in estimated 1 repetition maximum for the leg extension following 8 weeks of resistance training. Figure 14 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA found no significant differences at baseline and homogeneity of variances was confirmed by Levine's test. ANCOVA found a significant condition difference for both BFR and END when compared to

the control group (p < 0.05). The two-way repeated measures ANOVA showed that there was also a significant condition*time interaction (p < 0.05).

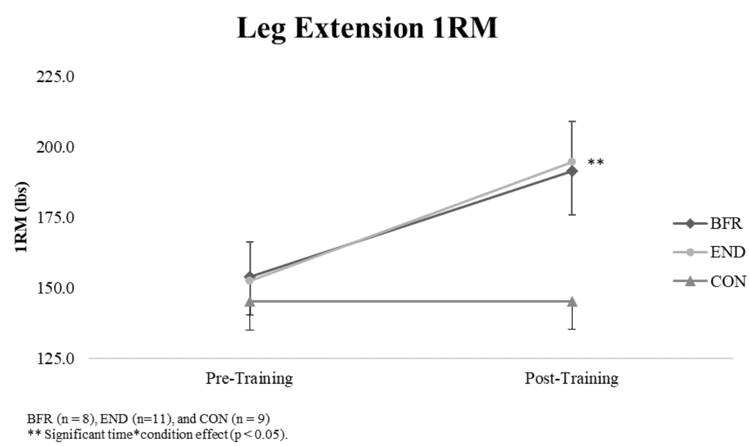


Figure 13. Leg Extension 1RM

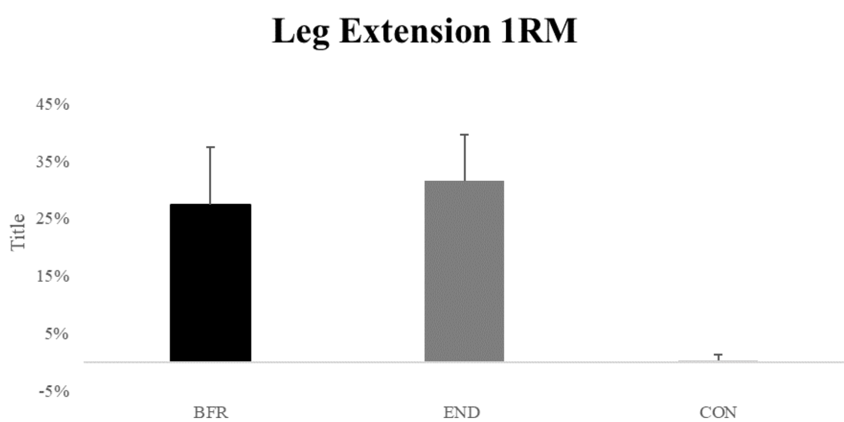


Figure 14. Leg Extension 1RM (% Change)

Figure 15 shows the change in estimated 1 repetition maximum for the leg curl following 8 weeks of resistance training. Figure 16 shows the corresponding percent change for each condition following the 8 weeks of resistance training. There were no significant differences at baseline and homogeneity of variances was confirmed by Levine's test. ANCOVA showed a significant difference for BFR when compared to the control group (p < 0.05). Two-way ANOVA with repeated measures found a significant condition*time interaction (p < 0.05).

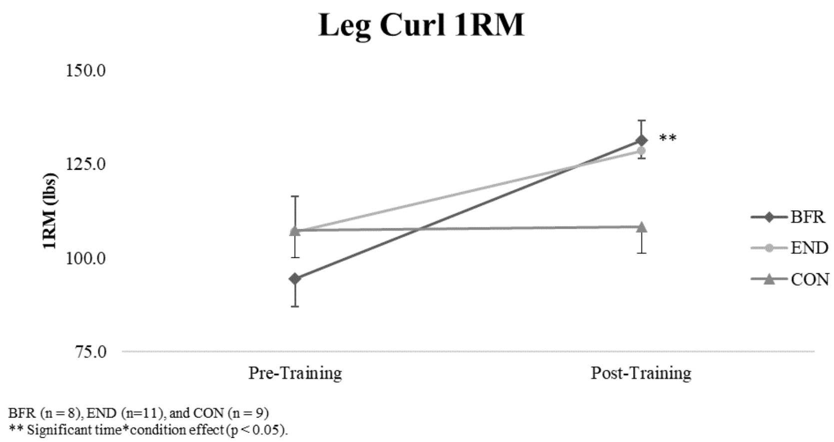


Figure 15. Leg Curl 1RM

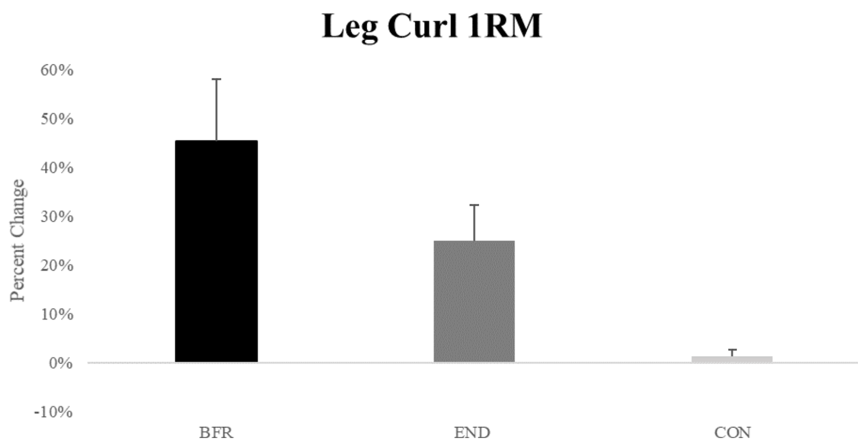


Figure 16. Leg Curl 1RM (% Change)

Figure 17 shows the change in estimated 1 repetition maximum for the chest press following 8 weeks of resistance training. Figure 18 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA detected no significant differences at baseline and homogeneity of variances was confirmed by Levine's test. A significant trend was found for both BFR ($p = 0.07$) and END ($p = 0.06$) when compared to the control group).

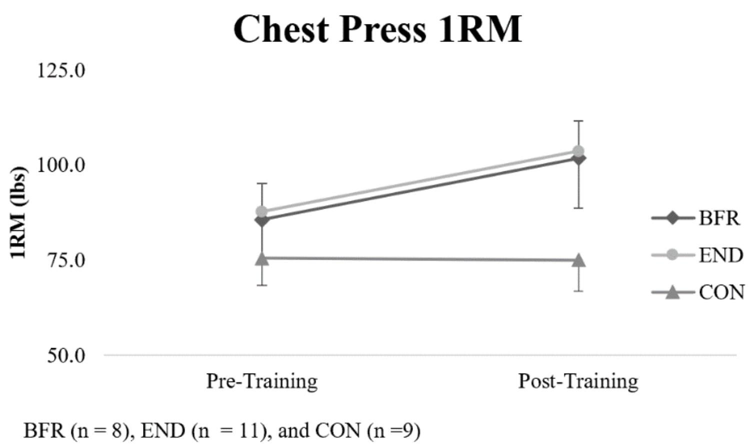


Figure 17. Chest Press 1RM

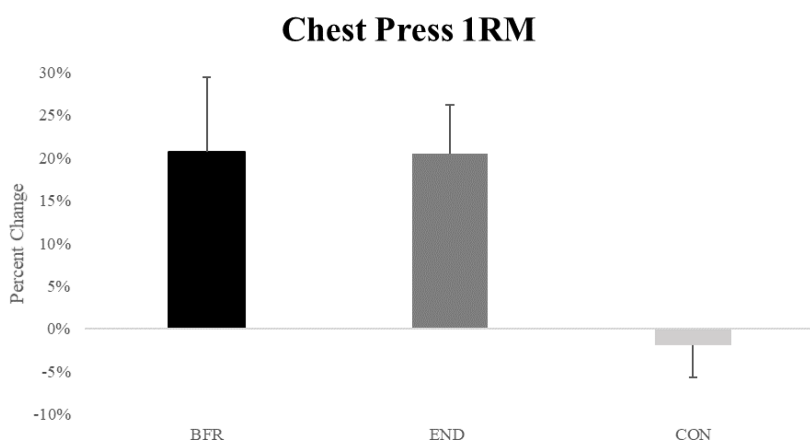


Figure 18. Chest Press 1RM (% Change)

Figure 19 shows the change in estimated 1 repetition maximum for the shoulder press following 8 weeks of resistance training. Figure 20 shows the corresponding percent change for each condition following the 8 weeks of resistance training. There were no significant differences at baseline and homogeneity of variances was confirmed by Levine's test. ANCOVA showed a significant difference for both BFR and END when compared to the control group ($p < 0.05$). Both training conditions significantly improved shoulder press 1-repetition maximum compared to the control.

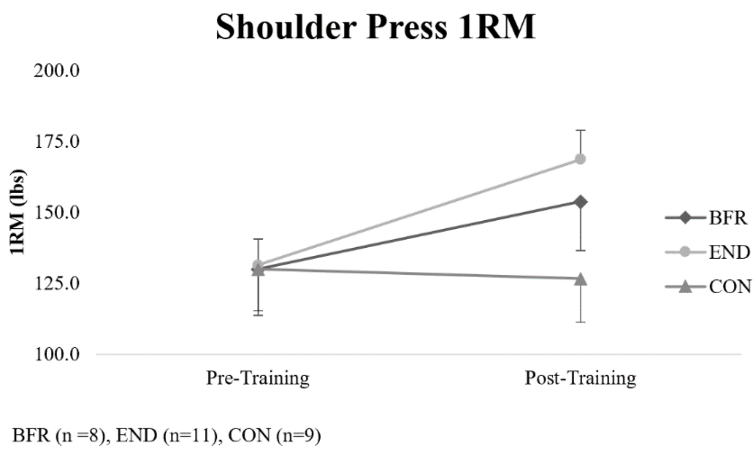


Figure 19. Shoulder Press 1RM

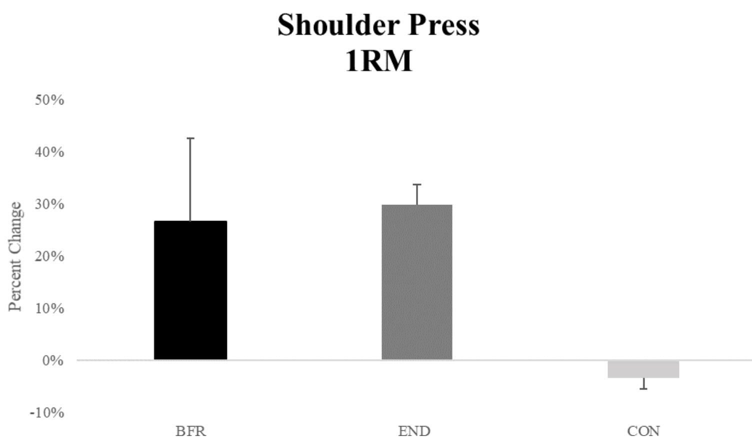


Figure 20. Shoulder Press 1RM (% Change)

Table 4 shows the changes in isometric and isokinetic muscle function within the three groups. There was a significant baseline difference in the following variable: Thorstensson mid strength. No other baseline differences were found. Homogeneity of variances was confirmed by Levine's test for all variables except Thorstensson mid strength and Thorstensson end strength. ANCOVA detected a significant difference for END when compared to the control group in the Isokinetic Leg Extension (60°/s) ($p = 0.002$). There were significant time main effects for MVC, ($p < 0.05$) in the Isokinetic Leg Extension (60°/s) and Isokinetic Leg Extension (180°/s).

Table 4. Isometric and Isokinetic Muscular Function

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Maximal Voluntary Contraction (n*m)	204.23 ± 11.71	223.2 ± 15.31	212.15 ± 9.96	231.23 ± 9.36	203.22 ± 11.09	212.32 ± 7.16
Isokinetic Leg Extension (60°/s) (n*m)	**150.81 ± 8.25**	**162.16 ± 8.06**	**139.11 ± 8.53**	**161.85 ± 8.26**	**129.85±7.26**	**132.42 ± 7.15**
Isokinetic Leg Extension (180°/s) (n*m)	107.34 ± 6.74	122.41 ± 8.75	100.45 ± 6.35	115.70 ± 5.23	99.80 ± 8.72	107.10.02
Thorstensson Initial Strength (n*m)	106.73 ± 6.86	120.20	106.09 ± 6.64	119.73 ± 4.52	97.70 ± 7.50	101.45 ± 8.33
Thorstensson Mid Strength (n*m)	69.69 ± 3.00	80.36 ± 7.92	62.09 ± 2.30	75.89 ± 7.92	57.95 ± 3.01	62.09 ± 2.52
Thorstensson End Strength (n*m)	49.05 ± 2.78	57.13 ± 4.95	45.95 ± 1.11	47.16 ± 2.21	43.04 ± 2.76	43.02 ± 1.78
Estimated Fast-Twitch Muscle Fiber Composition (%)	52.98 ± 3.66	52.65 ± 2.27	54.67 ± 4.13	60.97 ± 2.58	59.90 ± 2.72	59.20 ± 4.11
Estimated Slow-Twitch Muscle Fiber Composition (%)	47.02 ± 3.66	47.35 ± 2.27	45.33 ± 4.13	39.03 ± 2.58	40.10 ± 2.72	40.80 ± 4.11

Values are reported as means ± SE

Bold and Underlined data indicates a significant time main effect (p < 0.05)

Figure 21 shows the change in maximal voluntary contraction. One-way ANOVA found no significant differences at baseline. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found a significant time main effect ($p < 0.05$). Categories were reported together.

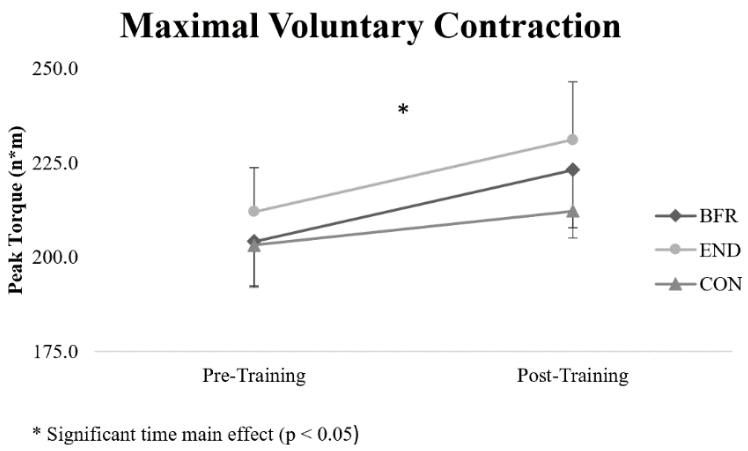


Figure 21. Maximal Voluntary Contraction

Figure 22 shows the results of the Isokinetic Leg Extension test at 60°/s. No significant baseline differences were detected by one-way ANOVA. ANCOVA found a significant difference for END when compared to the CON. A significant time main effect was found ($p < 0.05$). Categories were reported together.

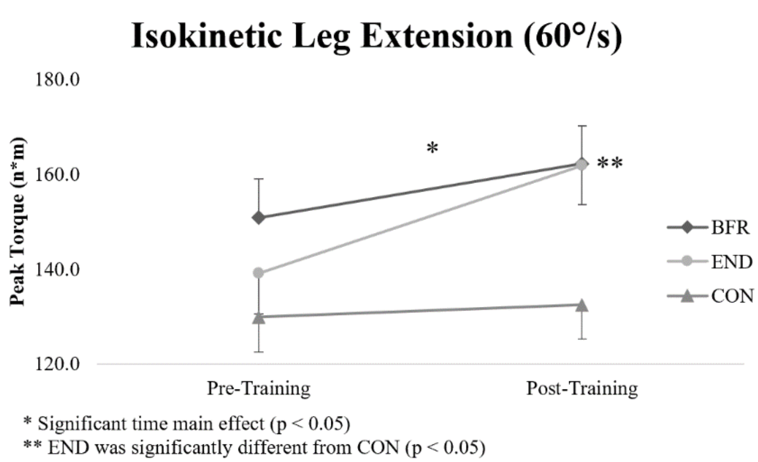


Figure 22. Isokinetic Leg Extension (60°/s)

Figure 23 shows the results of the Isokinetic Leg Extension (180°/s) following 8 weeks of training or control. No significant baseline differences were detected. A significant time main

effect was seen by ANOVA ($p < 0.05$). No other differences were detected and the categories were reported together.

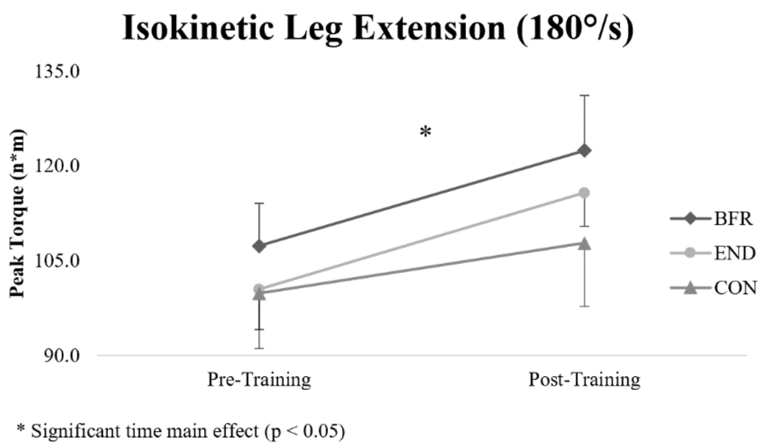


Figure 23. Isokinetic Leg Extension (180°/s)

Neuromuscular Function

The present study found a significant time main effect on maximal voluntary contraction (MVC) amplitude root mean square (rms) for both the vastus lateralis and vastus medialis, as well as a condition*time interaction for the same two muscles in the BFR group. Rectus Femoris showed a small and insignificant increase in RMS. The normalized amplitude RMS for isokinetic 60°/s and isokinetic 180°/s both showed no significant change.

Table 5 shows the effects on the root mean square of maximal voluntary contraction of the quadriceps, after 8 weeks of training. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test for all the variables listed. Both vastus medialis (VM) and vastus lateralis (VL) showed a statistically significant time main effect ($p < 0.05$). A condition*time interaction was also seen for both END-VM and BFR-VL ($p < 0.05$). Figure 24 shows the changes in root mean square of maximal voluntary contraction of the right quadriceps.

Table 5. Maximal Voluntary Contraction - Root Mean Square

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (μV)	**1.52E-04**	**2.04E-04**	**2.17E-04**	**2.65E-04**	**2.35E-04**	**2.13E-04**
Rectus Femoris (μV)	1.59E-04	2.23E-04	2.03E-04	2.42E-04	1.72E-04	1.89E-04
Vastus Lateralis (μV)	**2.04E-04**	**2.80E-04**	**2.54E-04**	**2.79E-04**	**2.34E-04**	**1.86E-04**

Values are reported as mean

Bold and Underlined data was statistically significant time main effect ($p < 0.05$)

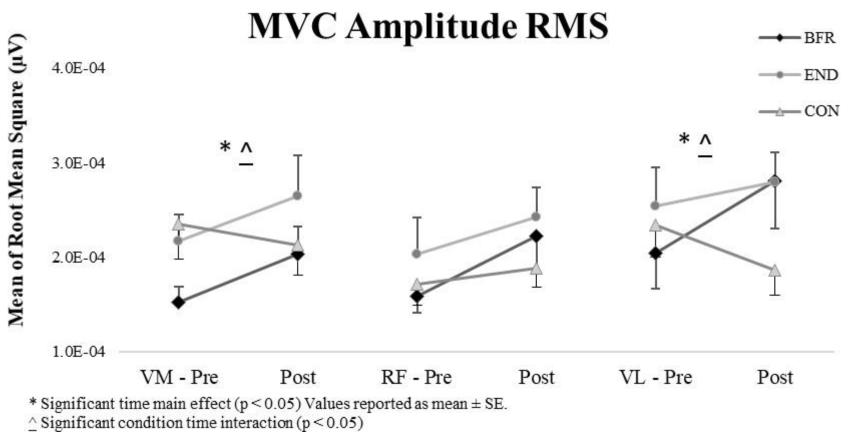


Figure 24. MVC Amplitude Root Mean Square

Table 6 and table 7 show the effects on the root mean square of isokinetic 60°/s and isokinetic after 8 weeks of training. No significant baselines differences between groups were detected and homogeneity of variances was confirmed by Levene’s test. No significant differences were found between groups. Two-way ANOVA with repeated measures detected no significant main effects or interactions.

Table 6. Isokinetic 60 °/s – Normalized Root Mean Square

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (%)	86.88 ± 6.00	83.13 ± 5.62	72.37 ± 3.98	77.49 ± 4.49	80.70 ± 6.43	85.60 ± 7.27
Rectus Femoris (%)	75.53 ± 4.74	74.20 ± 3.59	64.22 ± 4.74	73.06 ± 4.05	80.18 ± 9.45	75.92 ± 4.77
Vastus Lateralis (%)	78.02 ± 6.12	80.69 ± 3.79	70.85 ±3.66	74.51 ± 4.39	77.66 ± 2.60	80.96 ± 5.64

Values are reported as means ± SE

Bold and Underlined data indicates a significant time main effect (p < 0.05)

Table 7 shows the effects on the root mean square of the isokinetic 180°/s test. No significant baselines differences were detected. Homogeneity of variance was confirmed by Levene's test. No significant differences were detected by ANCOVA. No significant main effects or interactions were detected.

Table 7. Isokinetic 180 °/s – Normalized Root Mean Square

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (%)	94.55 ± 4.62	88.32 ± 5.29	70.16 ± 4.56	75.55 ± 8.61	83.84 ± 6.98	92.97 ± 7.63
Rectus Femoris (%)	75.38 ±5.62	78.68 ± 5.86	68.17 ± 5.57	67.17 ±5.86	86.96 ± 7.64	85.40 ± 7.87
Vastus Lateralis (%)	78.41 ± 4.13	85.37 ± 6.45	73.25 ± 5.16	71.16 ± 4.32	78.31 ± 6.09	86.40 ± 7.52

Values are reported as means ± SE

Bold and Underlined data indicates a significant time main effect (p < 0.05)

Table 8 shows the effects on the mean amplitude during a maximal voluntary contraction. No significant baseline differences were detected and homogeneity of variances was confirmed by Levene's test. ANCOVA detected no significant differences between groups. Both vastus medialis and vastus lateralis showed a statistically significant time main effect ($p < 0.05$). Figure

25 shows the changes in amplitude mean of maximal voluntary contraction of the right quadriceps.

Table 8. Maximal Voluntary Contraction – Amplitude Mean

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (μV)	**<u>1.48E-04</u>**	**<u>1.99E-04</u>**	**<u>2.11E-04</u>**	**<u>2.60E-04</u>**	**<u>2.30E-04</u>**	**<u>2.06E-04</u>**
Rectus Femoris (μV)	1.54E-04	2.17E-04	1.99E-04	2.38E-04	1.68E-04	1.83E-04
Vastus Lateralis (μV)	**<u>1.98E-04</u>**	**<u>2.75E-04</u>**	**<u>2.47E-04</u>**	**<u>2.74E-04</u>**	**<u>2.28E-04</u>**	**<u>1.80E-04</u>**

Values are reported as mean
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)

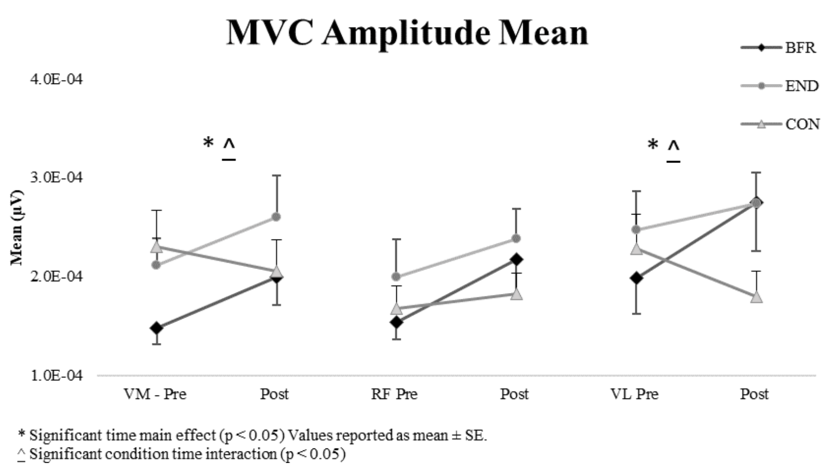


Figure 25. MVC Amplitude Mean

Table 9 shows the effects on the amplitude mean of isokinetic 60°/s test after 8 weeks of training. One-way ANOVA found a significant baseline difference in vastus medialis (180°/s). No other baselines differences between groups were detected and homogeneity of variances was confirmed by Levene’s test. No significant differences were found between groups. Two-way ANOVA with repeated measures found no significant main effects or interactions.

Table 9. Isokinetic 60 °/s – Normalized Amplitude Mean

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (%)	82.60 ± 5.62	81.83 ± 5.44	69.81 ± 3.80	75.04 ± 4.53	77.86 ± 6.61	81.81 ± 6.63
Rectus Femoris (%)	70.88 ± 4.57	72.64 ± 3.47	62.23 ± 4.58	70.19 ± 4.19	76.59 ± 9.32	73.46 ± 4.19
Vastus Lateralis (%)	74.18 ± 5.50	78.90 ± 3.74	68.27 ± 3.56	72.02 ± 4.37	74.06 ± 2.82	77.27 ± 5.45

Values are reported as means ± SE

Bold and Underlined data was statistically significant time main effect (p < 0.05)

Table 10 shows the effects on amplitude mean of the isokinetic 180°/s test. One-way ANOVA found a significant baseline difference for vastus medialis. No other baselines differences were detected. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found no significant main effects or interactions for any of the variables tested.

Table 10. Isokinetic 180 °/s – Normalized Amplitude Mean

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (%)	87.35 ± 3.32	84.55 ± 3.99	65.75 ± 3.45	73.20 ± 4.15	80.34 ± 6.87	86.18 ± 6.53
Rectus Femoris (%)	69.42 ± 4.72	73.93 ± 6.22	64.43 ± 4.14	63.97 ± 2.91	81.85 ± 7.23	80.81 ± 4.69
Vastus Lateralis (%)	72.46 ± 4.45	80.80 ± 5.09	68.20 ± 3.42	68.38 ± 2.93	73.96 ± 5.82	80.69 ± 6.55

Values are reported as means ± SE

Bold and Underlined data was statistically significant time main effect (p < 0.05)

Table 11 shows the effects on the median frequency of maximal voluntary contraction of the quadriceps after 8 weeks of training. One-way ANOVA found no significant baseline differences between groups. Homogeneity of variances was confirmed by Levene's test for only the vastus lateralis. ANCOVA detected no significant differences between groups. Two-way ANOVA with repeated measures found that both vastus medialis and vastus lateralis showed a statistically significant time main effect ($p < 0.05$) and condition*time interactions ($p < 0.05$).

Figure 26 shows the changes in median frequency of maximal voluntary contraction of the right quadriceps.

Table 11. Maximal Voluntary Contraction – Median Frequency

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis	**71.90 ± 2.37***	**67.91 ±1.40***	**76.43 ± 5.40***	**78.01 ± 3.47***	**69.29 ± 3.93***	**72.57 ± 3.19***
Rectus Femoris	74.64 ± 2.40	78.71 ± 2.68	86.48 ± 5.16	82.82 ± 4.42	85.37 ± 3.64	86.78 ± 3.05
Vastus Lateralis	**71.29 ± 4.89***	**79.35 ± 8.90***	**76.76 ± 4.74***	**81.14 ± 3.81***	**77.65 ± 4.00***	**70.65 ± 4.71***

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect (p < 0.05)
* Indicates a significant condition*time interaction (p < 0.05)

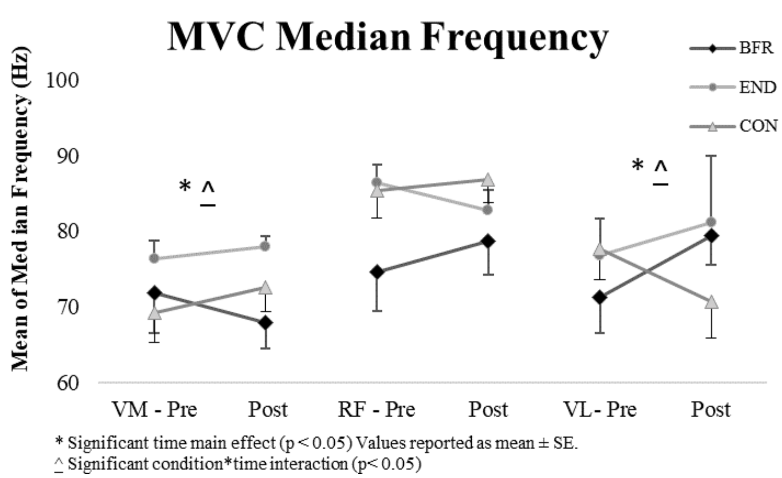


Figure 26. MVC Median Frequency

Table 12 shows the effects on the median frequency during the isokinetic 60°/s test. No significant baseline differences between groups were detected. Homogeneity of variances was confirmed by Levene's test for rectus femoris and vastus lateralis. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures detected no main effects or interactions.

Table 12. Isokinetic 60 °/s – Normalized Median Frequency

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (%)	82.60 ± 5.62	81.83 ± 5.44	69.81 ± 3.80	75.04 ± 4.53	77.86 ± 6.61	81.81 ± 6.63
Rectus Femoris (%)	70.88 ± 4.57	72.64 ± 3.47	62.23 ± 4.58	70.19 ± 4.19	76.59 ± 9.32	73.46 ± 4.19
Vastus Lateralis (%)	74.18 ± 5.50	78.90 ± 3.74	68.27 ± 3.56	72.02 ± 4.37	74.06 ± 2.82	77.27 ± 5.45

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)

Table 13 shows the effects on the median frequency during the isokinetic 180°/s test. No significant baseline differences were detected by one-way ANOVA. Homogeneity of variances was only confirmed for rectus femoris and vastus lateralis. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures detected no significant time main effects or conditions.

Table 13. Isokinetic 180 °/s – Normalized Median Frequency

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Vastus Medialis (%)	87.35 ± 3.32	84.55 ± 3.99	65.75 ± 3.45	73.20 ± 4.15	80.34 ± 6.87	86.18 ± 6.53
Rectus Femoris (%)	69.42 ± 4.72	73.93 ± 6.22	64.43 ± 4.14	63.97 ± 2.91	81.85 ± 7.23	80.81 ± 4.69
Vastus Lateralis (%)	72.46 ± 4.45	80.80 ± 5.09	68.20 ± 3.42	68.38 ± 2.93	73.96 ± 5.82	80.69 ± 6.55

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)

Body Composition

Table 14 shows the effects on body composition after 8 weeks of training. One-way ANOVA found no significant baselines differences between groups. ANCOVA detected no significant differences between groups. Two-way ANOVA with repeated measures found no significance for all condition and time main effects or condition*time interactions.

Table 14. Dxa Scan Results

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Total Mass (kg)	93.13 ± 3.09	93.05 ± 2.59	92.5 ± 5.24	92.84 ± 5.20	83.22 ± 2.50	83.00 ± 2.62
Lean Mass (g)	56481.5 ± 884.82	57518.6 ± 1035.02	56471.64 ± 2413.94	57298.45 ± 2404.69	52826.67 ± 1220.10	52676.11 ± 1360.92
Lean Tissue (%)	61.06 ± 1.57	62.11 ± 1.52	61.65 ± 1.28	62.32 ± 1.29	63.67 ± 0.97	63.61 ± 1.01
Fat Mass (g)	33516.3 ± 2672.31	32393.00 ± 2383.32	32835.09 ± 2857.92	32348.9 ± 2855.22	27314.22 ± 1573.27	27258.22 ± 1595.78
Fat Mass (%)	34.54 ± 1.66	34.49 ± 1.60	34.87 ± 1.37	34.22 ± 1.37	32.62 ± 1.04	32.66 ± 1.06
Android Fat (%)	46.42 ±2.60	45.74 ± 2.40	44.99 ± 2.02	44.74 ± 1.97	44.08 ± 1.57	44.37 ± 1.57
Gynoid Fat (%)	35.32 ± 1.53	33.92 ± 1.44	34.90 ± 1.51	33.70 ± 1.48	30.86 ± 1.10	30.34 ± 1.03
Android-Gynoid Ratio	1.32 ± 0.04	1.34 ± 0.05	1.29 ± 0.04	1.33 ± 0.03	1.44 ± 0.06	1.47 ± 0.07
Estimated visceral Adipose Tissue (g)	1978.6 ± 175.29	1836.6 ± 145.57	2120.73 ± 300.07	2077.82 ± 302.14	1870.56 ± 209.6	1839.11 ± 302.14
Bone Mineral Density (g*cm3)	1.34 ± 0.05	1.28 ± 0.04	1.33 ± 0.03	1.32 ± 0.04	1.47 ± 0.07	1.30 ± 0.03

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)

Figure 27 shows the change in total mass following 8 weeks of resistance training. Figure 28 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA found no significant baseline differences. Levene's test indicated unequal variances ($p = 0.03$). ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures detected no significant time main effects or condition*time interactions.

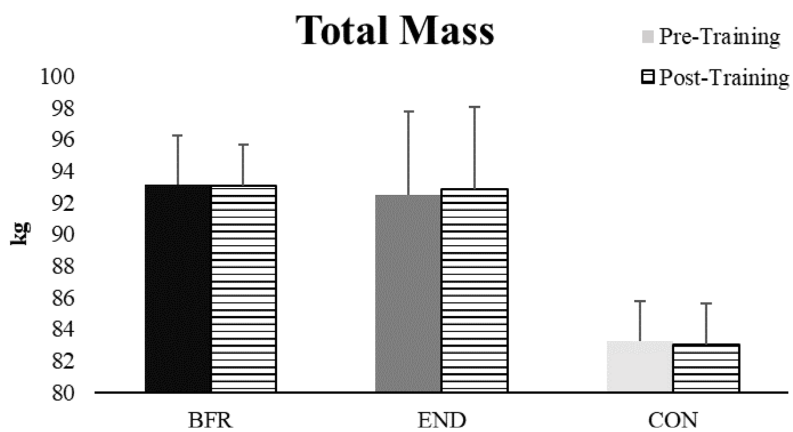


Figure 27. Change in Total Mass

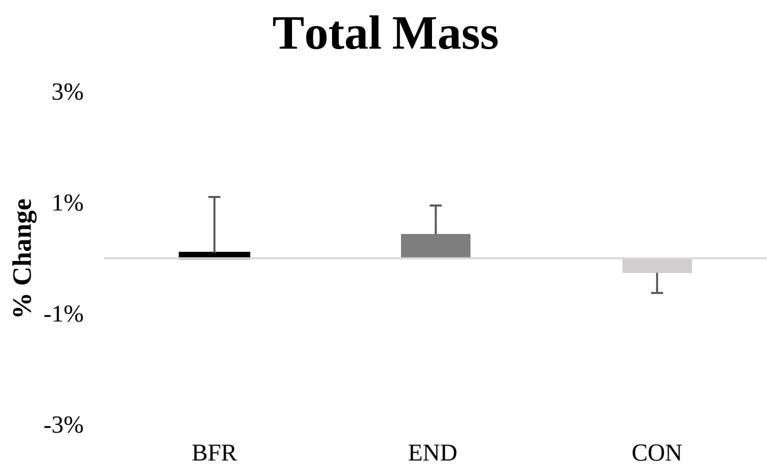


Figure 28. Change in Total Mass (%)

Figure 29 shows the change in lean mass following 8 weeks of resistance training. Figure 30 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA detected no significant baseline differences. Levene's test indicated unequal variances ($p < 0.05$). ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures detected no significant time main effects or interactions.

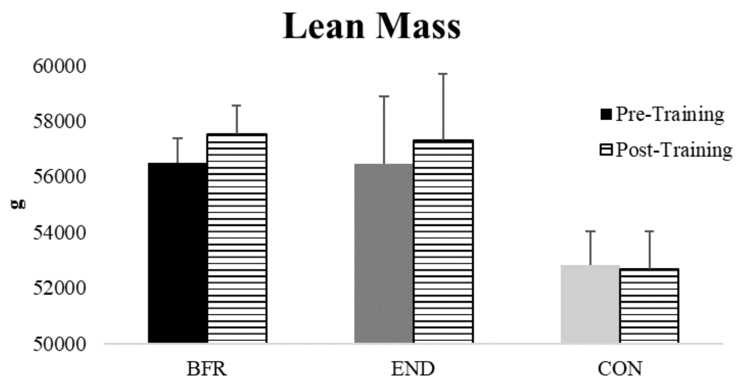


Figure 29. Change in Lean Mass

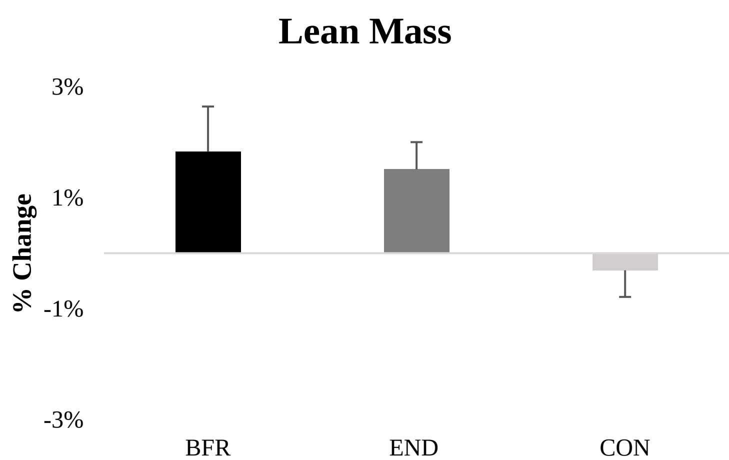


Figure 30. Change in Lean Mass (%)

Figure 31 shows the change in fat mass following 8 weeks of resistance training. Figure 32 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA found no significant baseline differences. Homogeneity of variances was confirmed by Levene's test. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found no significant main effects or interactions. Categories were reported together.

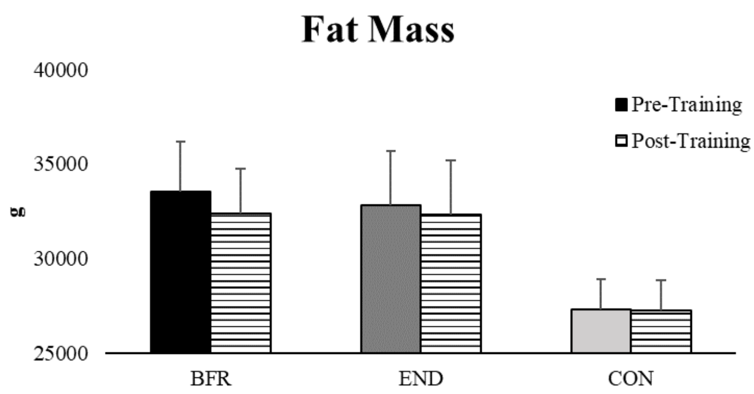


Figure 31. Change in Fat Mass

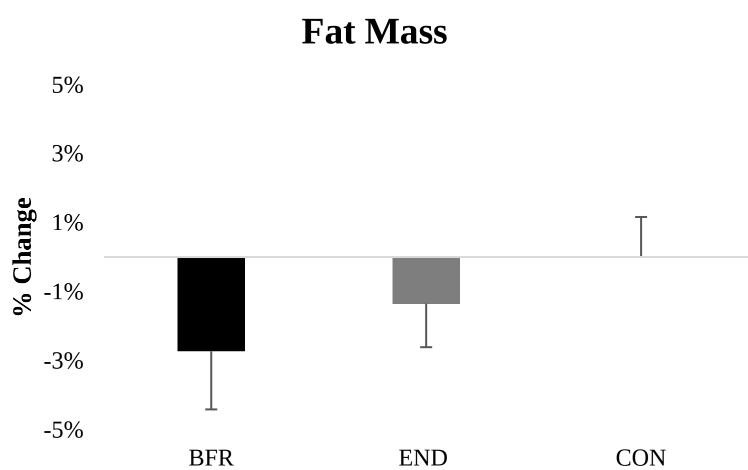


Figure 32. Change in Fat Mass (%)

Figure 33 shows the change in android fat mass following 8 weeks of resistance training. Figure 34 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were detected by one-way ANOVA. Levene's test confirmed homogeneity of variances. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures detected no significant main effects or interactions.

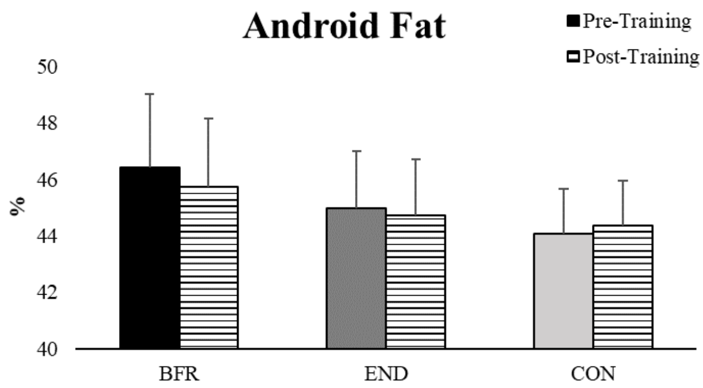


Figure 33. Change in Android Fat Mass

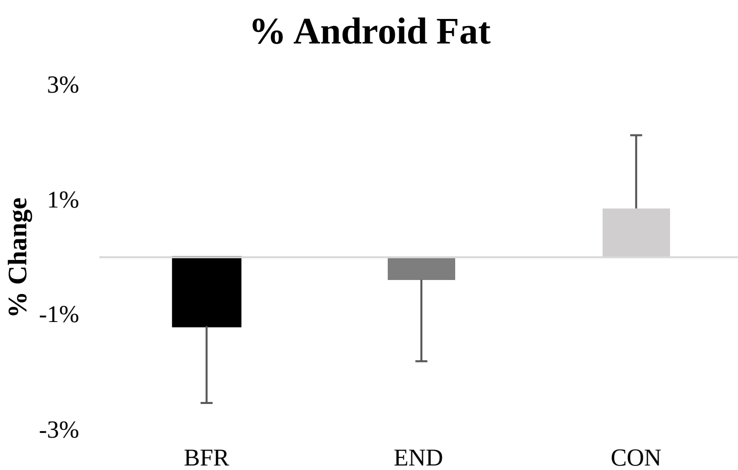


Figure 34. Change in Android Fat Mass (%)

Figure 35 shows the change in gynoid fat mass following 8 weeks of resistance training. Figure 36 shows the corresponding percent change for each condition following the 8 weeks of resistance training. There were no significant baseline differences detected by one-way ANOVA. Homogeneity of variances was confirmed by Levene's Test. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found no significant time main effects or interactions.

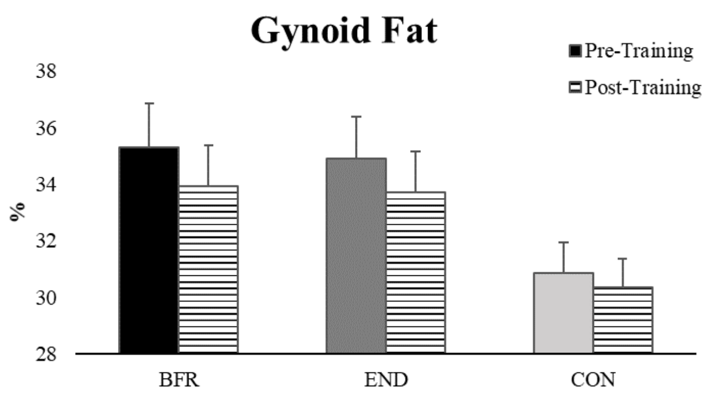


Figure 35. Change in Gynoid Fat Mass

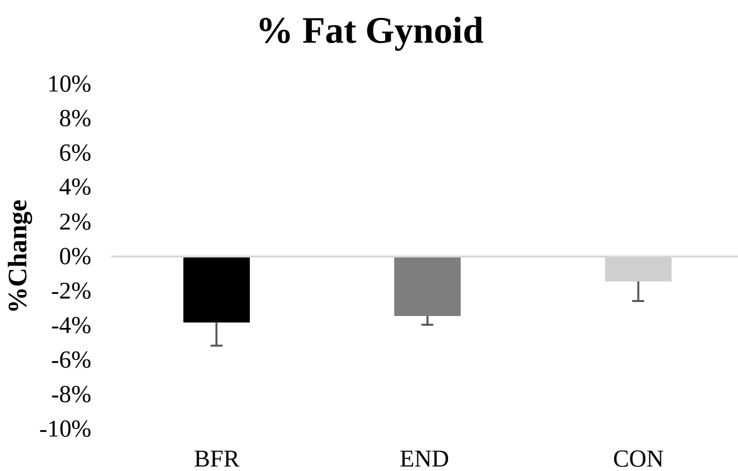


Figure 36. Change in Android Fat Mass (%)

Figure 37 shows the change in estimated visceral adipose (EVAT) tissue following 8 weeks of resistance training. Figure 38 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were detected by one-way ANOVA. Homogeneity of variance was confirmed by Levene's test. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures detected a trend for a time main effect ($p = 0.051$).

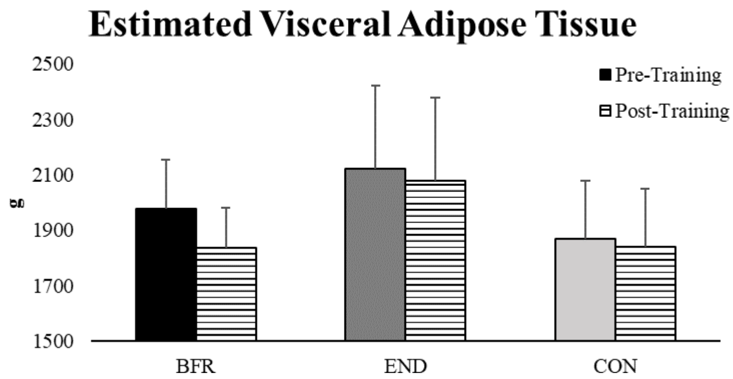


Figure 37. Change in Estimated Visceral Adipose Tissue

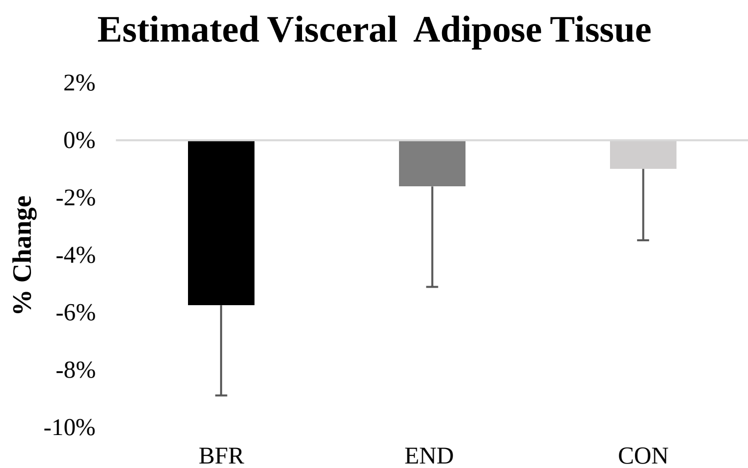


Figure 38. Change in Estimated Visceral Adipose Tissue (%)

Table 15 shows the effects on tissue composition in the arms after 8 weeks of training. No significant baselines differences between groups were detected. There was a significant difference in fat tissue (%) and fat tissue (g) ($p < 0.05$) in the BFR group when compared to the CON group.

Table 15. Body Composition - Arms

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	**31.58 ± 1.83****	**30.15 ± 2.03****	**28.97 ± 0.75**	**28.45 ± 0.74**	**26.10 ± 0.88**	**26.09 ± 1.09**
Fat Tissue (g)	3601.30 ± 332.98**	3438.30 ± 297.41**	3174.00 ± 202.91	3159.55 ± 202.92	2585.00 ± 148.85	2614.67 ± 176.84
Lean Tissue (g)	7328.2 ± 261.64	7602.9 ± 296.10	7218.00 ± 339.77	7455.65± 394.54	6833.44 ± 216.91	6905.56 ± 224.95
Bone Mineral Content (g)	457.70 ± 14.24	448.40 ± 14.56	450.45 ± 17.86	453.73 ± 18.46	441.89 ± 15.43	445.00 ± 15.89
Total Mass (kg)	11.40 ± 0.48	11.48 ± 0.39	10.85 ± 0.55	11.07 ± 0.39	9.87 ± 0.33	9.96 ± 0.36

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)
** There was a significant difference in fat tissue (g) and (%) ($p < 0.05$) when compared to CON

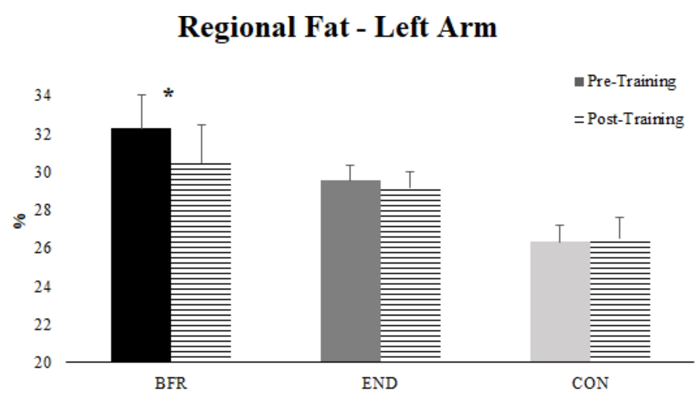
Table 16 shows the effects on body composition in the left arm after 8 weeks of training. Baseline differences were found in the following variables: Fat tissue (%), fat tissue (g), and total mass (kg). No significant baselines differences between groups were detected for lean tissue and bone mineral content. Homogeneity of variances was confirmed by Levene’s test. There was a significant difference in fat tissue % ($p < 0.05$) in the blood flow restriction group.

Table 16. Body Composition - Left Arm

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	**32.27 ± 178****	**30.5 ± 1.95****	**29.55 ± 0.78**	**29.21 ± 0.80**	**26.33 ± 0.86**	**26.54 ± 1.06**
Fat Tissue (g)	1813.2 ± 165.57	1746.8 ± 144.79	1564.09 ± 90.46	1595 ± 94.66	1263.78 ± 74.78	1291.89 ± 81.51
Lean Tissue (g)	3593.6 ± 129.47	3746.00 ± 134.84	3487.64 ± 157.34	3630.00 ± 178.63	3295.22 ± 122.03	3340.00 ± 106.93
Bone Mineral Content (g)	224.8 ± 7.43	222.3 ± 7.42	220.73 ± 7.56	223.27 ± 7.51	216.56 ± 8.89	217.67 ± 8.52
Total Mass (kg)	5.63 ± 0.24	5.71 ± 0.19	5.27 ± 0.24	5.45 ± 0.27	4.77 ± 0.19	4.84 ± 0.17

Values are reported as means ± SE
Bold and Underlined data was statistically significant time main effect ($p < 0.05$)
**There was a significant difference in fat tissue (%) and (g) compared to CON ($p < 0.05$)

Figure 39 shows the change in fat tissue in the left arm following 8 weeks of resistance training. Figure 40 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA detected significant baseline differences (p=0.01). ANCOVA found The BFR group had significantly less fat tissue (%) in the left arm compared to both the END (27.6% ± 0.4 vs. 29.1% ± 0.4, p=0.04) and CON (27.6% ± 0.4 vs. 29.9% ± 0.5, p<0.01) groups following training. No significant time main effects or condition interactions were detected.



* BFR was significantly different compared to END (p = 0.04) CON (p < 0.01)

Figure 39. Change in Fat Tissue in Left Arm

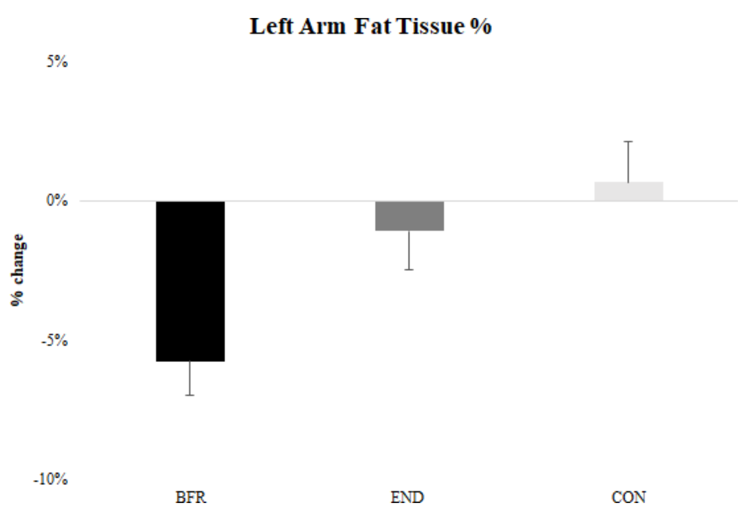


Figure 40. Change in Left Arm Fat Tissue (%)

Figure 41 shows the change in lean tissue in the left arm following 8 weeks of resistance training. Figure 42 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were detected by one-way ANOVA. ANCOVA found no significant differences between groups. No significant time main effects or condition*time interactions were found by two-way ANOVA with repeated measures.

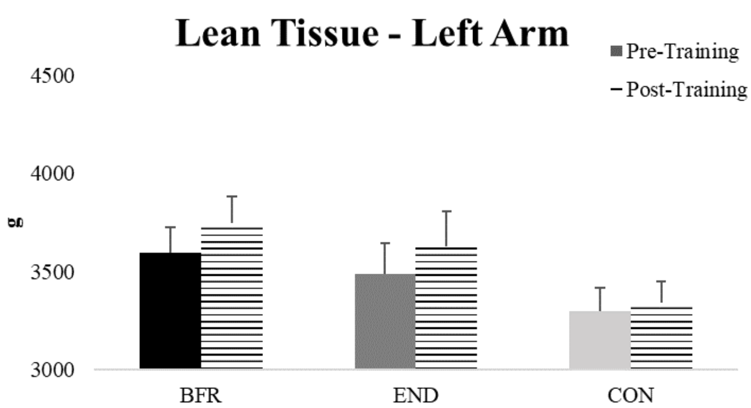


Figure 41. Change in Left Arm Lean Tissue

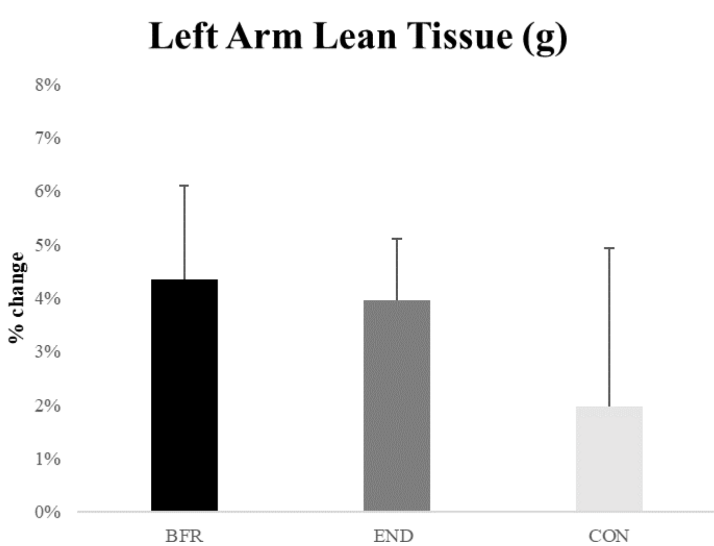


Figure 42. Change in Left Arm Lean Tissue (%)

Table 17 shows the effects on body composition in the right arm after 8 weeks of training. One-way ANOVA found significant baseline differences in the following variables: fat tissue (%) and fat tissue (g). ANCOVA detected a significant difference in fat tissue % (p = 0.043) in the blood flow restriction group. The BFR group had significantly lower right arm percent fat when compared to the CON group (26.9% ± 0.5 vs. 28.7% ± 0.5, p = 0.04) following training.

Table 17. Body Composition - Right Arm

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	**<u>31.13 ± 1.83</u>**	**<u>29.61 ± 2.20</u>**	**<u>28.66 ± 0.74</u>**	**<u>27.71 ± 0.71</u>**	**<u>25.80 ± 1.00</u>**	**<u>25.64 ± 1.16</u>**
Fat Tissue (g)	1800.2 ± 166.82	1707.60 ± 152.53	1609.64 ± 114.68	1563.55 ± 111.32	1321.00 ± 87.56	1322.67 ± 99.72
Lean Tissue (g)	3758.7 ± 133.96	3865.20 ± 166.09	3730.27 ± 188.99	3825.64 ± 222.72	3538.22 ± 111.84	3565.56 ± 126.61
Bone Mineral Content (g)	233.20 ± 7.47	227.50 ± 7.42	229.82 ± 10.59	230.45 ± 11.26	225.44 ± 7.70	227.44 ± 7.70
Total Mass (kg)	6.29 ± 0.53	5.8 ± 0.20	5.56 ± 0.30	5.62 ± 0.34	5.09 ± 0.18	5.11 ± 0.21

Values are reported as means ± SE
<u>Bold and Underlined data</u> indicates a significant time main effect (p < 0.05)

Figure 43 shows the change in fat tissue in the right arm following 8 weeks of resistance training. Figure 44 shows the corresponding percent change for each condition following the 8 weeks of resistance training. One-way ANOVA detected significant baseline differences for the following variables: fat (%) (p = 0.02) and fat (g) (p = 0.04). Homogeneity of variances was confirmed by Levene's test. Homogeneity of variances was confirmed by Levene's test. ANCOVA detected a significant difference in fat tissue % (p = 0.043) in the blood flow restriction group. The BFR group had significantly lower right arm percent fat when compared to the CON group (26.9% ± 0.5 vs. 28.7% ± 0.5, p = 0.04) following training. No significant time

main effects or condition*time interactions were seen by two-way ANOVA with repeated measures.

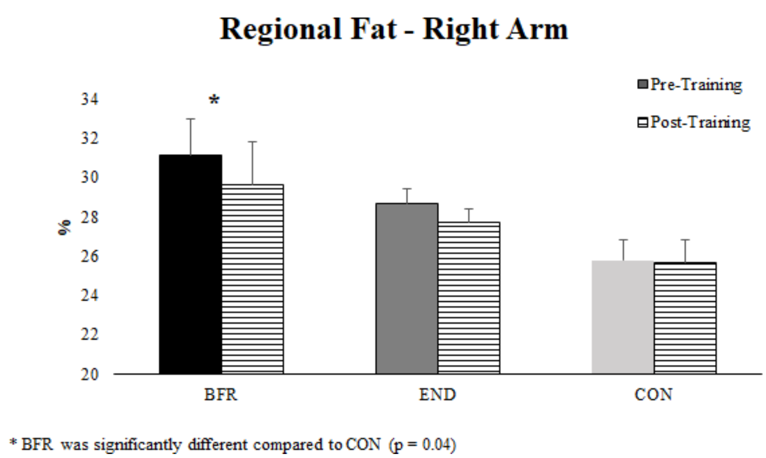


Figure 43. Change in Fat Tissue in Right Arm

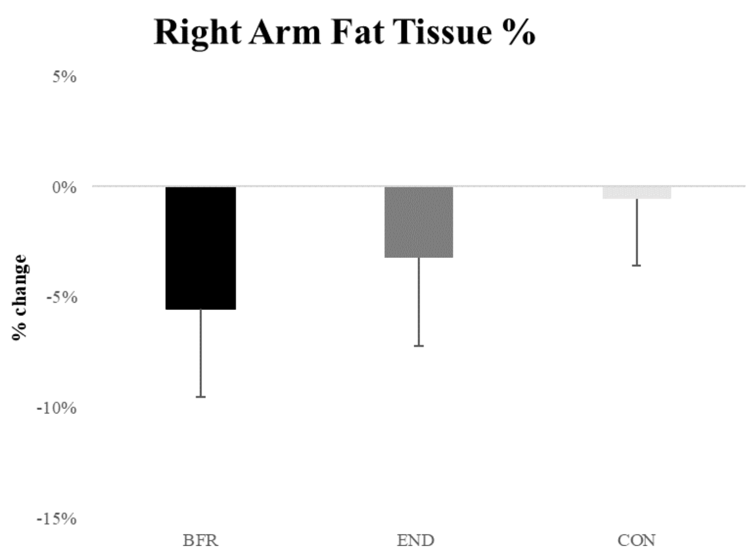


Figure 44. Change in Right Arm Fat Tissue (%)

Figure 45 shows the change in lean tissue in the right arm following 8 weeks of resistance training. Figure 46 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were detected by one-way ANOVA. Homogeneity of variances were confirmed by Levene’s test. ANCOVA found no

significant differences between groups. No significant main effects or condition*time interactions were seen.

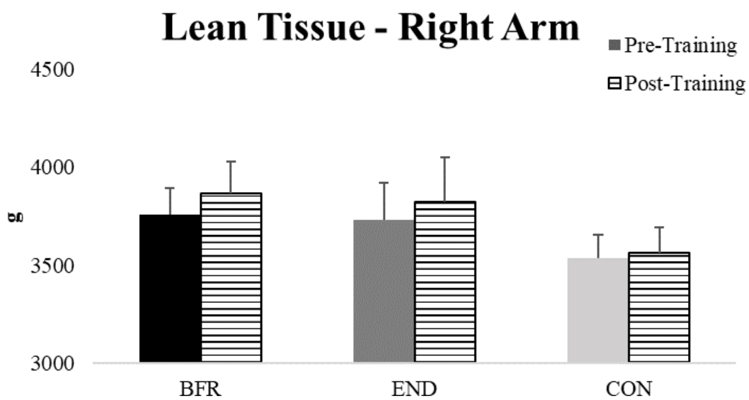


Figure 45. Change in Lean Tissue in Right Arm

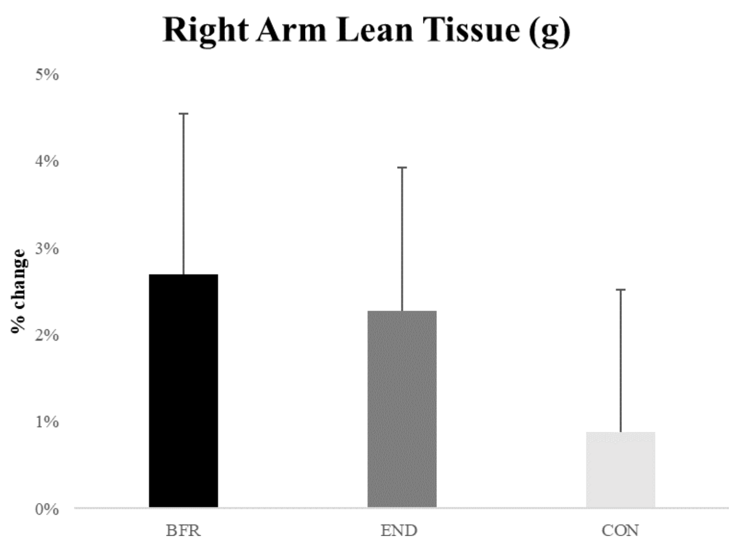


Figure 46. Change in Right Arm Lean Tissue (%)

Table 18 shows the effects on tissue composition in the legs after 8 weeks of training. Significant baseline differences were found for the following variables: Fat tissue (%) and fat tissue (g). No other significant baselines differences between groups were detected. Unequal variances were assumed for the following variables: fat tissue (g) (p = 0.004) and bone mineral

content (p = 0.005). No significant differences between groups were found by ANCOVA. A trend was seen in lean tissue (p = 0.09).

Table 18. Body Composition - Legs

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	29.82 ± 1.33	28.62 ± 1.24	29.52 ± 1.24	28.44 ± 1.31	25.38 ± 0.72	25.36 ± 0.68
Fat Tissue (g)	8725.0 ± 626.11	8345.0 ± 472.32	8691.36 ± 739.46	8456.91 ± 755.38	6529.67 ± 268.1	6470.67 ± 251.78
Lean Tissue (g)	19465.2 ± 467.11	19778.6 ± 476.43	19116.73 ± 928.30	19617.64 ± 948.10	18015.89 ± 429.15	17901.22 ± 501.97
Bone Mineral Content (g)	1171.20 ± 34.56	1166.40 ± 37.45	1199.00 ± 55.33	1199.00 ± 55.20	1141.89 ± 36.80	1139.11 ± 39.78
Total Mass (kg)	29.35 ± 0.90	29.29 ± 0.68	29.02 ± 1.61	29.27 ± 0.68	25.70 ± 0.60	25.51 ± 0.67

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect (p < 0.05)

Table 19 shows the effects on body composition in the left leg after 8 weeks of training. Baseline differences were found in the following variables: Fat Tissue (%). Levene's test indicated homogeneity of variances. No other significant baseline differences between groups were detected. No significant differences were found between groups.

Table 19. Body Composition - Left Leg

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	29.69 ± .1.35	28.59 ± 1.27	29.52 ± 1.14	28.25 ± 1.26	25.44 ± 0.63	25.36 ± .0.69
Fat Tissue (g)	4380.40 ± 507.17	4180.60 ± 245.57	4314.73 ± 362.92	4160.91 ± 365.17	3254.56 ± 121.88	3213.22 ± 148.63
Lean Tissue (g)	9805.3 ± 227.82	9925.30 ± 241.68	9491.00 ± 458.19	9741.91 ± 469.86	8955.78 ± 199.05	8853.89 ± 249.42
Bone Mineral Content (g)	586.00 ± 15.13	583.50 ± 15.85	603.36 ±29.23	600.45 ± 29.05	571.67 ± 18.41	571.11 ± 19.79
Total Mass (kg)	14.77 ± 0.48	14.68 ± 0.36	14.40 ± 0.81	14.50 ± 0.80	12.78 ± 0.28	12.64 ± 0.37

Values are reported as means ± SE
Bold and Underlined data was statistically significant time main effect (p < 0.05)

Figure 47 shows the change in fat tissue in the left leg following 8 weeks of resistance training. Figure 48 shows the corresponding percent change for each condition following the 8 weeks of resistance training. Levene's test indicated unequal variances (p = 0.006). ANCOVA found no significant differences between groups. Two-way ANOVA found no significant time main effects or condition*time interactions.

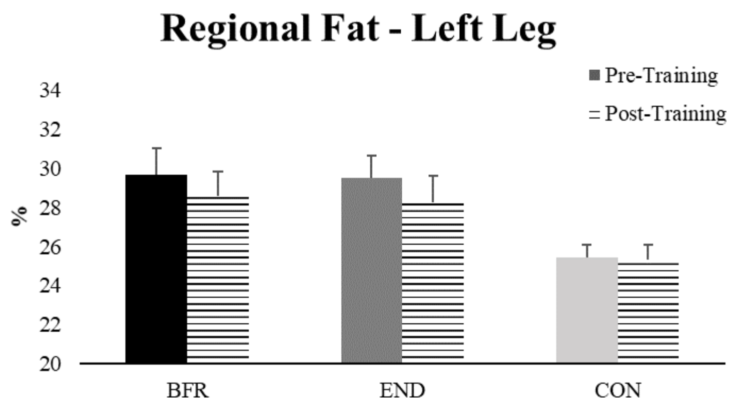


Figure 47. Change in Fat Tissue in Left Leg

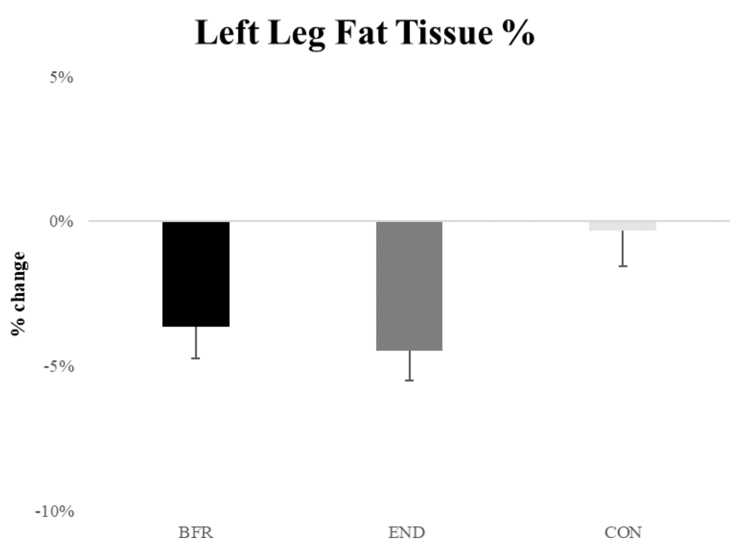


Figure 48. Change in Left Leg Fat Tissue (%)

Figure 49 shows the change in lean tissue in the left leg following 8 weeks of resistance training. Figure 50 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were detected. Levene’s test indicated unequal variances (p = 0.001). ANCOVA found no significant differences between groups.

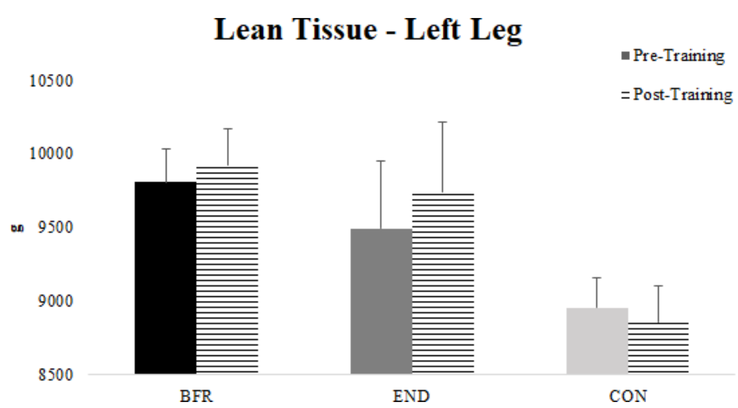


Figure 49. Change in Lean Tissue in Left Leg

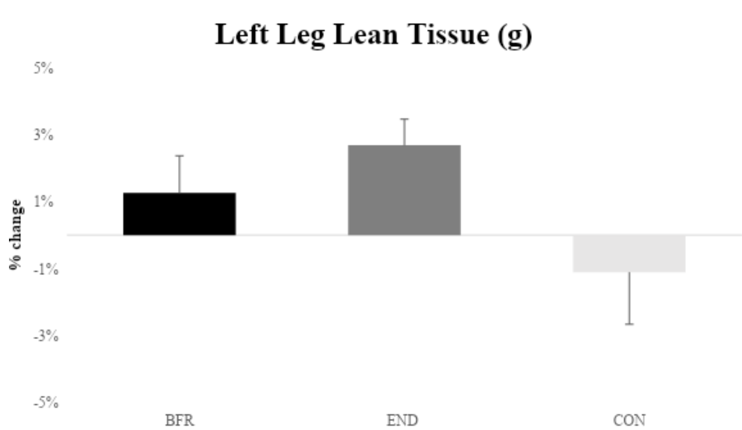


Figure 50. Change in Left Leg Lean Tissue (%)

Table 20 shows the effects on body composition in the right leg after 8 weeks of training. There were significant baseline differences in the following variables: Fat tissue (%) and fat

tissue (g). No significant baseline differences between groups were detected. Unequal variances were indicated by Levene's test for lean tissue (p=0.01).

Table 20. Body Composition Right Leg

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	29.94 ±1.33	28.62 ± 1.22	29.57 ± 1.36	28.73 ± 1.37	25.34 ± 0.84	25.32 ± 0.73
Fat Tissue (g)	4344.60 ±296.42	4164.10 ± 229.54	4376.45 ± 380.55	4296.09 ± 394.28	3275.33 ± 149.68	3257.56 ± 116.62
Lean Tissue (g)	9650.8 ± 255.79	9853.5 ± 247.68	9625.64 ± 474.90	9875.64 ± 479.56	9060.11 ± 236.69	9047.44 ± 272.19
Bone Mineral Content (g)	582.90 ± 21.75	582.70 ± 23.12	595.55 ± 26.44	598.55 ± 26.41	570.22 ± 18.74	568.11 ± 20.27
Total Mass (kg)	14.58 ± 0.44	14.59 ± 0.34	14.61 ± 0.81	14.79 ± 0.83	12.89 ± 0.33	12.87 ± 0.34

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)

Figure 51 shows the change in fat tissue in the right leg following 8 weeks of resistance training. Figure 52 shows the corresponding percent change for each condition following the 8 weeks of resistance training. No significant baseline differences were detected. Homogeneity of variance was confirmed by Levene's test. ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found no significant time main effects or interactions.

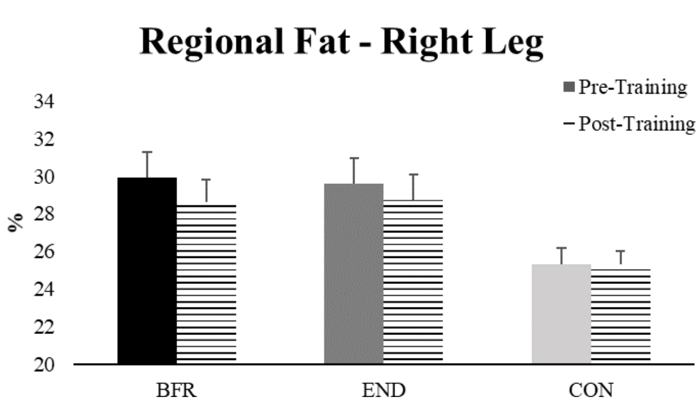


Figure 51. Change in Fat Tissue in Right Leg

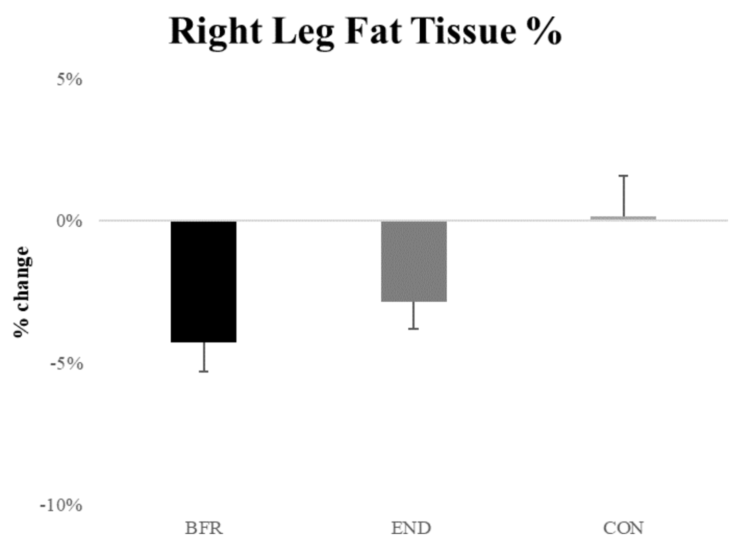


Figure 52. Change in Right Leg Fat Tissue (%)

Figure 53 shows the change in lean tissue in the right leg following 8 weeks of resistance training. Figure 54 shows the corresponding percent change for each condition following the 8 weeks of resistance training. Baseline differences were not statistically significant. Levene's test indicated unequal variances (p=0.01). ANCOVA found no significant differences between groups. Two-way ANOVA with repeated measures found no significant main effects or interactions.

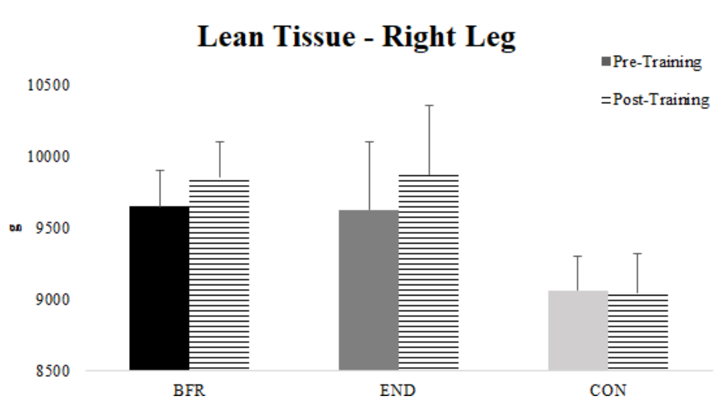


Figure 53. Change in Lean Tissue in Right Leg

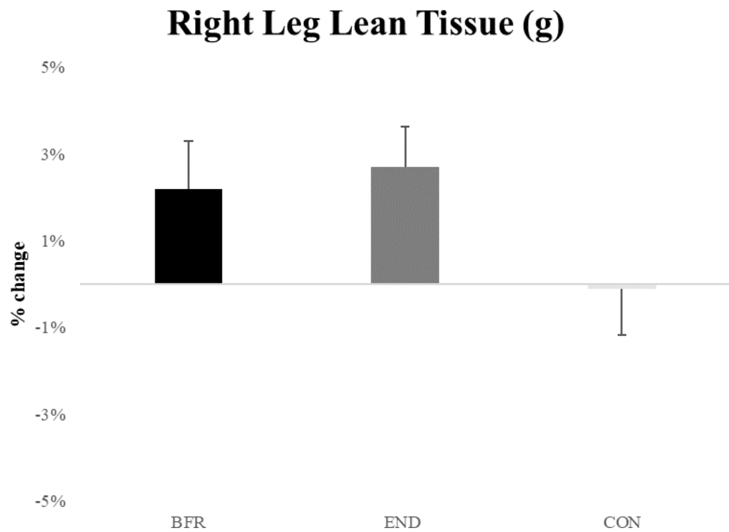


Figure 54. Change in Right Leg Lean Tissue (%)

Table 21 shows the effects on body composition in the torso after 8 weeks of training. No significant baseline differences between groups were detected by one-way ANOVA. ANCOVA found no significant differences were found between groups.

Table 21. Body Composition - Torso

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	42.19 ± 2.16	41.21 ± 2.16	41.13 ± 1.78	40.76 ± 1.72	39.89 ± 1.43	39.99 ± 1.49
Fat Tissue (g)	20107.40 ± 1843.23	19514.1 ± 1705.64	19833.82 ± 1936.44	19585.09 ± 1919.31	17192.67 ± 1238.47	17164.89 ± 1261.45
Lean Tissue (g)	26029.9 ± 265.88	26430.00 ± 398.45	26334.82 ± 1137.18	26401.55 ± 1083.25	24499.89 ± 628.62	24400.22 ± 658.21
Bone Mineral Content (g)	938.40 ± 36.98	931.60 ± 33.34	967.73 ± 60.81	961.18 ± 59.95	959.22 ± 39.03	955.11 ± 32.10
Total Mass (kg)	47.07 ± 1.90	46.87 ± 1.65	47.15 ± 3.04	46.95 ± 2.98	42.66 ± 1.68	42.52 ± 1.68

Values are reported as means ± SE
Bold and Underlined data indicates a significant time main effect ($p < 0.05$)

Tables 22 and 23 show body composition for the right and left halves of the body, respectively. Figure 55 shows the changes in lean tissue for the left side of the body. No significant baseline differences were detected by one-way ANOVA. ANCOVA detected

significant differences in lean tissue when comparing the BFR group and END group to the CON group. The changes in lean tissue that occurred on the left side of the body were statistically different when compared to the CON (p = 0.04). Figure 56 shows the changes in lean tissue for the right side of the body. The right side of the body saw no significant changes.

Table 22. Body Composition - Right Side

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	36.13 ± .1.61	35.12 ± 1.59	34.98 ± 1.37	34.35 ± 1.38	32.59 ± 1.07	32.52 ± 1.05
Fat Tissue (g)	16767.80 ± 1339.01	16198.4 ± 1216.74	16495.64 ± 1464.02	16227.36 ± 1470.44	13592.56 ± 765.12	13551.56 ± 762.94
Lean Tissue (g)	28258.7 ± 496.17	28687.2 ± 551.59	28365.18 ± 1229.42	28702.55 ± 1252.29	26376.44 ± 650.31	26391.67 ± 700.63
Bone Mineral Content (g)	1610.00 ± 29.87	1579.80 ± 25.54	1611.82 ± 73.75	1600.55 ± 75.51	1543.44 ± 41.71	1547.33 ± 52.91
Total Mass (kg)	46.69 ± 1.55	46.46 ± 1.38	46.48 ± 2.67	46.53 ± 2.69	41.52 ± 0.28	41.48 ± 1.28

Values are reported as means ± SE
Bold and Underlined data was statistically significant time main effect (p < 0.05)

Table 23. Body Composition - Left Side

Variables	Blood Flow Restriction (n=10)		Endurance (n=11)		Control (n=10)	
	Pre	Post	Pre	Post	Pre	Post
Fat Tissue (%)	36.16 ± 1.59	35.05 ± 1.59	34.98 ± 1.31	34.31 ± 1.29	32.69 ± 1.00	32.82 ± 1.08
Fat Tissue (g)	16748.20 ± 1336.47	16194.50 ± 1169.24	16339.36 ± 1404.19	16123.55 ± 1391.30	13721.67 ± 810.50	13706.56 ± 840.39
Lean Tissue (g)	**28200.9 ± 416.01**	**28831.40 ± 493.33**	**28106.27 ± 1191.86**	**28498.09 ± 1196.49**	**26450.22 ± 594.25**	**26284.11 ± 678.30**
Bone Mineral Content (g)	1572.20 ± 42.01	1549.90 ± 40.24	1576.09 ± 70.34	1579.91 ± 71.23	1533.22 ± 51.89	1524.22 ± 47.11
Total Mass (kg)	46.48 ± 1.54	46.57 ± 1.22	46.00 ± 2.59	46.19 ± 2.57	41.70 ± 1.31	41.51 ± 1.37

Values are reported as means ± SE
Bold and Underlined data change was statistically different compared to CON (p = 0.04)

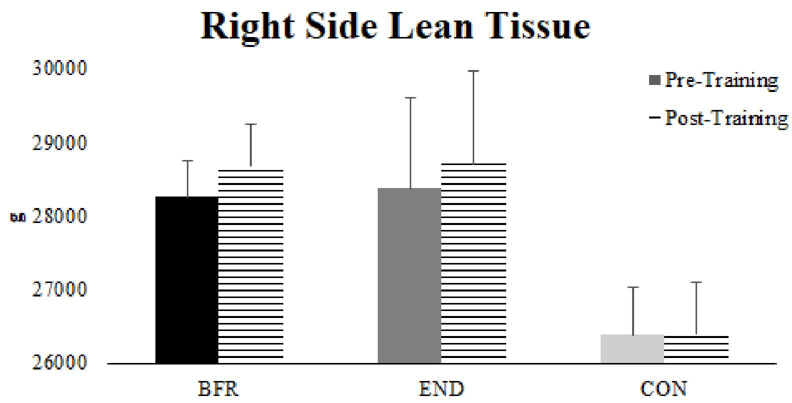


Figure 55. Changes in Lean Tissue - Right Side

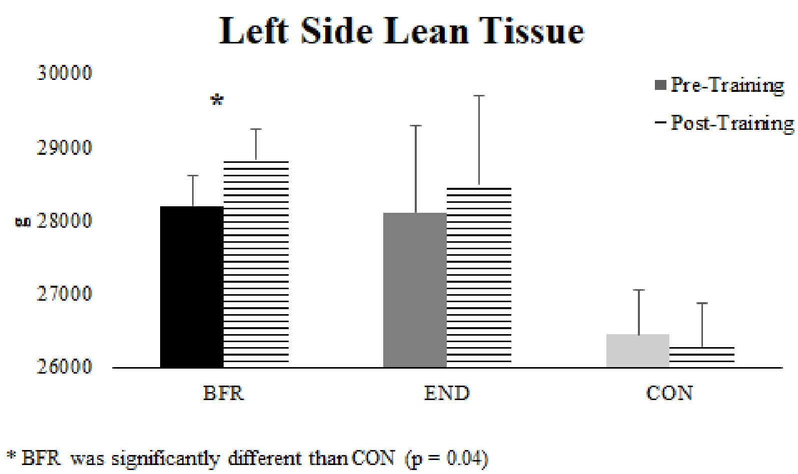


Figure 56. Changes in Lean Tissue - Left Side

CHAPTER V

DISCUSSION

The purpose of this study was to compare the effects of 8 weeks of resistance exercise training with or without BFR on: 1) hemodynamics; 2) arterial elasticity; 3) muscular force production; 4) electromyography (EMG); and 5) body composition in males between the ages of 50 to 70 years of age.

Hemodynamic Responses

While time main effects were seen in aortic mean arterial pressure (MAP), MAP during systole, and MAP during diastole, no condition significantly improved those variables. The literature has shown that resistance training influences blood pressure dependent on training intensity. Low-to-Moderate intensity resistance training has shown to reduce blood pressure. Collier (2008) found that resistance training in middle-aged adults improved blood pressure following 4 weeks of resistance training at a moderate intensity in pre-hypertensive or stage 1 hypertensive subjects. Blood pressure reductions have been shown to be greater in individuals with higher baseline blood pressure values (MacDonald et al., 2016). The loss of arterial elasticity is part of the aging process, and this loss of elasticity leads to hypertension, among other things. In the present study, the mean brachial blood pressure for the BFR group and the END group was 130/79 mmHg and 136/84 mmHg, respectively. According to the AHA, these values would suggest that the participants of the present study were either pre-hypertensive or stage 1 hypertensive (American Heart Association, 2017). Despite being in the above normal

range, no condition significantly reduced blood pressure following 8 weeks of resistance training. Since the participants in the present study were healthy older individuals, it is possible that the current study was not long enough to result in a significant change in blood pressure or mean arterial pressure. Several studies that were longer in duration improved blood pressure, but only in the ones that used BFR as a treatment (Taaffe et al., 2006; Williams et al., 2013; Grutter Lopes et al., 2021). A resistance training intervention of 20 weeks significantly reduced central SBP and DBP as well as brachial DBP following the intervention (Taaffe et al., 2006). Williams et al. (2013) conducted a 16-week long resistance training intervention in both older women and older men and found no changes in blood pressure in men but a small, significant change in women. A 12-week long resistance training intervention comparing low-intensity (30% 1RM) BFR training and high-intensity (70% 1RM) traditional resistance training did find that BFR significantly reduce systolic and diastolic BP by 7 mmHg and 5 mmHg, respectively. It is important to note that 60% of the volunteers of the aforementioned study were women that may suggest that BP changes at this stage of life may be sex-dependent (Grutter Lopes et al., 2021).

There has been some concern regarding the effects of BFR training on the cardiovascular system. Spranger et al. (2015) worried that the use of BFR training could lead to an overactivation of the exercise pressor reflex, an overactivation of muscle reflexes leading to sympathetic hyperactivity, and a subsequent increased risk of cardiovascular-related adverse events. While the present study did not measure hemodynamic response acutely or immediately following training sessions, the training adaptations showed no difference between the two conditions. Resting heart rate and mean arterial pressure remained relatively unchanged following the training completion. These findings were also observed in other studies: a 12-month resistance training intervention where participants completed nearly 75% of all training

sessions (Schmidt et al., 2014), a 12-week intervention comparing using BFR with resistance bands (Yasuda et al., 2014), and a meta-analysis on the effect of different exercises on resting heart rate found that traditional resistance training had no effect on resting heart rate (Reimers et al., 2018). The results of the present study suggest that the changes elicited by BFR and traditional resistance training in this population are primarily local changes and not systemic changes.

The research is lacking on the effects of resistance training on variables such as pulse pressure and ejection duration. The data showed no change in these variables following 8 weeks of resistance training in middle-aged males with no history of resistance training. This could suggest that not enough time had elapsed, and, therefore, not enough volume accumulated to elicit any significant change.

Arterial Compliance

Arterial compliance, reported via pulse wave velocity, was not significantly affected by the training interventions of this study. This is promising as low intensity BFR training mimics high intensity resistance training without negatively impacting arterial elasticity. According to the literature, the effect of resistance training on arterial compliance is mixed and thought to be largely influenced by training intensity.

Miyachi and colleagues (2004) took 28 healthy young males through 4 months of resistance training and reported a reduction of 19% in central arterial compliance (increased stiffness measured at the carotid artery site) and no change in peripheral arterial compliance (measured at the femoral artery site). This is of particular interest, as Heusinkveld et al., (2019) have speculated that the augmentation index (AIx), a measure used to describe systemic arterial stiffness, is dependent on cardiac and vascular parameters, and not just general vascular

parameters as previously thought. The training sessions for the Miyachi study were performed at a high intensity of 80%1RM, whereas the present study used moderate intensities no greater than 65%1RM. Regarding central arterial compliance and peripheral arterial compliance, the present study reported central arterial compliance as carotid-femoral pulse wave velocity (cfPWV), and peripheral arterial compliance as carotid-radial pulse wave velocity (crPWV) as well as femoral-ankle pulse wave velocity (faPWV. Another study took 32 young males through 12 weeks of resistance training at high or low intensities and found that central arterial stiffness, also cfPWV, was reduced regardless of intensity (Au et al., 2017). The present study had two months of resistance training, albeit in middle-aged males as opposed to the young males of the previous study mentioned and found no significant effects on cfPWV. This agrees with other studies in the same population (Cortez-Cooper et al., 2008; Maeda et al., 2006; Yasuda et al., 2009).

Every time the heart beats, the left ventricle creates a pulse wave that travels away from the heart. The pulse wave is partially reflected because of interactions with the elastic arteries, generating multiple reflected waves that travel back toward the heart (Nichols, 2005). The waves occur at several sites of the artery tree, and reflected waves summate in transit and form a composite wave that eventually arrives at the left ventricle (Westerhof, 2012). The arrival of the reflected pulse wave during late systole increases ventricular afterload, impacts left ventricular remodeling, and affects systolic and diastolic function (Borlaug et al., 2007; Chirinos et al., 2013; Zamani et al., 2014). The ratio of the amplitude of the backward wave to that of the forward wave is known as reflection magnitude and is strongly predictive of incident heart failure (Chirinos et al., 2014; Zamani et al., 2014). Reflection magnitude increases with age (Segers et al., 2007) and Zamani and colleagues (2014) found a 18%-32% increase in mortality for every 10% increase in reflection magnitude. The significant difference in reflection

magnitude found in the current study suggests that low intensity BFR resistance training can reduce cardiac workload, specifically left ventricular workload We can speculate that if BFR training can reduce reflection magnitude, then over time with consistent training, it could create a positive domino effect of a reduction in cardiac workload, arterial stiffness, and all-cause mortality. These findings could guide future research in larger populations.

Strength Measures

This study compared BFR resistance training at low intensity (20-40% 1RM) to moderate intensity resistance training (40-60%1RM). Despite the difference in intensities, the data suggests that the resulting strength gains were nearly identical. The effectiveness of resistance training in improving strength in middle adulthood is well known (Frontera and Bigard, 2022; Borde, Hortobagyi, and Granacher, 2015). The ACSM position on resistance training intensities in older adults is that higher intensities result in greater strength gains (Chodzko-Zajko et al., 2009).

Similar increases in 1RM have been seen in this population using low-intensity resistance training and BFR for 4 weeks of lower body resistance training (Patterson & Ferguson, 2011). Karabulut et al. (2009) conducted a similar study using BFR on both upper and lower limbs in the same population. A notable difference was that this 2009 study compared low-intensity BFR resistance training to high-intensity resistance training (i.e., 80% 1RM), while the present study compared low-intensity BFR resistance training to moderate intensity (i.e., 40-65% 1RM). Both training groups in the 2009 study had similar increases in 1RM except for leg extension; the leg extension 1RM of the high-intensity group was significantly greater than the BFR group (Karabulut et al., 2009).

An interesting finding from the present study was the isokinetic and isometric tests showed no significant differences between groups. To be clear, there were improvements in both conditions, but the improvements did not reach the level of significance, with the exception of the isokinetic 60°/s test. The endurance (END) group results of the isokinetic 60°/s test were significantly different when compared to the control group. The isokinetic 60°/s test is considered a “strength test” and the isokinetic 180°/s test is seen as a “speed test,” specifically to measure endurance. The strength improvements seen in the BFR group agree with other studies (Colomer-Poveda et al., 2017; Hill et al., 2018; Patterson & Ferguson, 2011; Takarada et al., 2002; Takarada, et al., 2000). The difference seen in the isokinetic 60°/s test could probably be attributed to the higher load used by the endurance group, as higher loads induce greater mechanical tension, a primary driving force in strength gains (Schoenfeld, 2010). Given the short length of the present study (8 weeks), the authors may speculate that the changes in strength may be primarily due to neural adaptations rather than muscle hypertrophy (Côté et al., 1988; Vissing et al., 2008). The findings of the present study add to the body of knowledge that BFR resistance training at lower intensities can provide similar isotonic strength adaptations as resistance training at higher intensities.

Neuromuscular Function

Neural adaptations are primarily responsible for the training-induced strength gains, especially during the early phase of a resistance training program (Sale, 1988; Delmonico et al., 2009; Frontera et al., 2002). Additionally, longer training studies (24-52 weeks) are more effective at improving muscle strength in older adults versus short training periods (8-18 weeks) (Borde et al., 2015). The length of the present study was 8 weeks, which resulted in improved muscle strength, force production, and in electromyographic (EMG) activity.

. Multiple studies have shown that low-intensity BFR can increase electromyography (EMG) activity of the active muscles (Moritani et al., 1992; Takarada et al., 2000; 2002). The present study found that for the vastus lateralis and vastus medialis, there was an increased amplitude in EMG signals across interventions implying neuromuscular adaptation. This suggests that there was an increased number of active motor units, increased firing frequency, and/or greater motor unit synchronization that enhanced force production in these participants (Manimmanakorn et al., 2013; Yao et al., 2000). This could explain the increased amplitude mean seen during the maximal voluntary contraction (MVC) test. The results of the present study elicited different MDF values in different muscles when testing MVC: there was a significant decrease in vastus medialis (VM) MDF for BFR compared to the control, and VL and RF showed a small but insignificant increase. The increase in MDF suggests an improvement in neural adaptations as MDF is the total EMG power spectrum divided into two equal regions with equal amplitude (Oskoei & Hu, 2008; Phinyomark et al., 2012).

As mentioned earlier, increases in strength following a resistance training program have been attributed to neural adaptations followed by a combination of hypertrophic and neural adaptations (Moritani & deVries, 1979). It has been suggested that BFR reverses the order of this adaptation, with muscle hypertrophy being the primary cause for early-phase increase in strength (Loenneke et al., 2012). Studies that support this finding include two from Takarada et al. (2002; 2000), Hill et al., (2018), and Colomer-Poveda et al. (2017). The use of cuffs to modulate blood flow in the working limbs is characterized by a reduction in oxygen availability, thereby a high metabolite accumulation, which leads to a significant increase in fast-twitch muscle fiber recruitment (Moritani et al., 1992; Takarada et al., 2000; Yasuda et al., 2014). While evidence exists for the reversal of adaptation, this study does not support that theory, as there was no

significant increase in muscle mass but rather a significant change in neural adaptations, as reflected by changes in EMG output. The present study adds to the body of research that low-intensity BFR training follows the traditional paradigm of neuromuscular adaptations.

Body Composition

Body composition is the percentage of lean mass, fat mass, total body water, and bone in the body. The larger the amount of lean mass relative to the rest of the components of the body, the greater potential for force production. Strength adaptations following a resistance training program are attributed to neural and hypertrophic adaptations (Moritani & deVries, 1979). There are studies claiming that BFR defies this paradigm, though the present study does not support these claims (Colomer-Poveda et al., 2017; Hill et al., 2018; Loenneke et al., 2012; Takarada et al., 2002; Takarada, et al., 2000). It may be worth noting that the aforementioned studies used either magnetic resonance imaging (MRI) or ultrasound to measure change in muscle mass. The present study used dual x-ray absorptiometry (DXA). Comparative studies assessing DXA and MRI have shown strong associations for whole-body and regional scans (Wang et al., 1999; Zhao et al., 2013). When comparing percent change over time, the association is not as robust (Delmonico et al., 2008; Lee & Kuk, 2013). DXA is considered the "reference standard" and for this reason was used in the present study. There were significant changes in lean muscle mass on the left side of the body for the BFR group despite lifting lower loads than the END group. This change suggests that despite the lower workload, and therefore lower mechanical tension, BFR elicited the necessary metabolic stress to stimulate muscle hypertrophy (Pearson et al., 2015).

Body fat percentage did not show significant differences in either group regardless of intervention in the present study. The BFR group reduced corporal adiposity by 3%, while the END group saw a reduction of 2%. There was an inverse change in lean tissue, with the BFR

group increasing lean tissue by 3% and the END group by 2%. Both conditions increased left and right arm lean tissue by about 4% and 3%, respectively. Both legs saw an increase in lean tissue by about 3%. These small changes in lean tissue fall within the DXA's error range of 4% (Tavoian et al., 2019). It is largely accepted that longer training periods are more effective at improving lean mass (Borde et al., 2015). A meta-analysis by Peterson et al. (2011) suggested that resistance training programs with a mean length of 21 weeks (at 3 sets per week and with 75%1RM) was effective at significantly improving lean body mass in older adults. Future research should consider the length of the study as well as the modalities when measuring muscle mass.

Visceral adiposity is associated with a detrimental atherosclerotic cardiovascular disease due to its high levels of inflammatory cells, its association with metabolic syndrome, and insulin resistance markers (Schousboe et al., 2018). DXA estimated the change in visceral adipose tissue (EVAT) to have reduced by 6% in the BFR group, whereas the END group was no different from the control. With a p value of 0.051, these changes in EVAT were close, but ultimately did not exhibit a significant difference across the groups; despite this result, the results are promising A meta-analysis on the effects of exercise on visceral fat (Sabag et al., 2017) concluded that resistance training was not as effective as aerobic exercise in visceral adipose tissue reduction. The authors posit that, had the study duration been longer, there would have been a significant decrease in EVAT, challenging the results of the meta-analysis. This finding could impact future studies, as the location of adipose tissue stores (i.e., visceral vs. subcutaneous) can determine potential for adverse health outcomes (Targher et al., 2010).

To improve or maintain bone health, moderate-to-high-intensity resistance training exercises or high-impact exercises are recommended (American College of Sports Medicine,

2009). Despite its low-load nature, BFR coupled with resistance training has been shown to increase bone-specific alkaline phosphatase in older males (Karabulut et al., 2011). Participants trained for 10 weeks either using BFR and low-intensity resistance training or a high-intensity resistance training (20% and 80%, respectively). Following the training, blood samples revealed a 23% and 21% increase in circulating bone-marker concentrations for the high intensity group and the BFR group, respectively. A DXA scan was also performed, which revealed no significant change. Similarly, the present study found no change in bone mineral density via a DXA scan. While the DXA scans revealed no significant differences after 8 weeks of resistance training, perhaps a longer study would have allowed for such adaptations to occur. Studies comparing animals across the lifespan reveal that the adaptive capacity of bone diminishes over time, leading to bone loss (Birkhold, et al., 2014). Exercise can attenuate bone loss as well as fracture risk (Smith & Gilligan, 1991). The literature suggests that studies shorter than 6 months in duration will have no significant impact on bone mineral density (Hamilton et al., 2022; Souza et al., 2020). For example, a three-month long resistance training intervention did not significantly improve bone mineral density when compared to the control (i.e, non-exercising) group (Mosti et al., 2013).

Conclusions

The purpose of this study was to compare the effects of 8 weeks of resistance exercise training with or without BFR on: 1) hemodynamics; 2) arterial elasticity; 3) muscular force production; 4) electromyography (EMG); and 5) body composition in males between the ages of 50 to 70 years of age.

The research questions asked were:

1. Did both training groups significantly improve EMG activity compared to control?

2. Did both training groups significantly reduce arterial elasticity compared to control?
3. Did both training groups improve strength gains similarly?
4. Did both training groups significantly improve body composition compared to control?

Research Hypothesis 1. Both training groups will similarly improve EMG activity compared to control.

The results of the present study did support this hypothesis. It was hypothesized that the EMG activity in training groups would improve similarly to the training when compared to the control. Amplitude mean and root mean square (RMS) were significantly increased in both conditions for vastus medialis and vastus lateralis when compared to CON. BFR was not significantly different from END. Additionally, EMG variables for the isokinetic tests showed no differences between training groups. The similar responses in EMG activity imply that low-intensity BFR resistance training and traditional resistance training follow similar training adaptations over time.

Research Hypothesis 2. Both training will significantly improve arterial elasticity compared to control.

The present study's results did not support this hypothesis. It was hypothesized that both training groups would significantly improve arterial elasticity (reported as PWV) compared to the control group. The only significant difference between both groups was for reflection magnitude; BFR was significantly different when compared to END. Reflection magnitude as a measure of hemodynamics illustrates the potential for improved arterial elasticity; this implies that arterial elasticity can improve over time with a longer duration of training. No significant differences were seen for any other hemodynamic variables or pulse wave velocity.

Research Hypothesis 3. Both training groups will have similar strength gains.

This hypothesis was supported by the data. It was hypothesized that both groups would elicit similar strength increases following 8 weeks of resistance training despite training at different intensities. Both conditions significantly improved their 1RM tests when compared to the control but there was no significant difference when BFR was compared to END. Despite working at lower intensities, BFR was able to produce nearly identical strength gains as END. The isokinetic and isometric tests resulted in similar strength gains at all speeds tested. The END group's results for the isokinetic 60°/s were significantly different when compared to the CON group. Except for that test, BFR produced nearly the same strength gains as END despite the difference in intensities.

Research Hypothesis 4. Both training groups will significantly improve body composition compared to control.

This hypothesis was supported by the data. The change in lean mass reached significance for the left side of the body of the BFR group when compared to the CON. The change in fat mass for both training groups trended towards significance when compared to the CON. It was expected that bone mineral density (BMD) would not significantly change due to the short length of the study and that was confirmed by the results.

This study is the first of its kind to measure the effects of an 8-week resistance training program using low-intensity BFR versus moderate-intensity on body composition, muscle force production, neuromuscular adaptations, bone mineral density, and arterial elasticity in middle-aged males. This study showed that both conditions were equally effective at increasing strength while maintaining arterial compliance. This implies that low-intensity BFR could be an

alternative to moderate-intensity training, reducing potential barriers to exercise such as current or past injury and perceived difficulty.

There was a significant increase in lean tissue in the left side of the body for the BFR group, however, the primary driver of strength gains is most likely the neuromuscular adaptations. This is evident by the results of the EMG changes during the MVC tests. The MVC knee extension tests were performed with the right leg and not the left, where the change in lean tissue was seen. These findings support the currently accepted mechanism whereby neural adaptations precede morphological adaptations in strength gains.

In summary, BFR training at low intensity can provide similar benefits seen at higher intensities while reducing barriers to exercise, including the risk of injury that comes with heavier loads in middle-aged males. The main findings of this study are that low-intensity BFR is 1) effective at producing similar neuromuscular and strength gains, 2) effective at improving body composition, 3) and effective at maintaining arterial elasticity and hemodynamics compared to resistance training at higher intensities. The findings regarding reflection magnitude are significant, as one of the drawbacks to resistance training is that it increases arterial stiffness. If BFR does indeed reduce reflection magnitude, and eventually arterial elasticity, then BFR could provide all of the benefits of resistance training without any of the drawbacks. The results of this study could be useful in creating resistance training programs for healthy, middle-aged males new to exercise and extend their agency into later life. Future research should continue to investigate the "reverse paradigm" in BFR early-phase strength gains, as well as the low-frequency fatigue that may be affecting neural adaptations specifically in BFR resistance training. Researchers should also consider the effects of longer-term (i.e., ≥ 16 weeks) BFR resistance training on bone mineral density.

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APPENDIX

APPENDIX

DEFINITIONS

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

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

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

Hemodynamics – Analysis of the physical aspects of blood circulation

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

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

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

LIST OF ABBREVIATIONS

AIX – Augmentation Index

AIX 75 – Augmentation Index Normalized at 75 bpm

ANCOVA – Analysis of Covariance

ANOVA – Analysis of Variance

AP – Aortic Augmented Pressure

BFR – Blood Flow Restriction

BPM – Beats Per Minute

CON – control

DBP – Diastolic Blood Pressure

DXA/DEXA – Dual-Energy X-ray Absorptiometry

END – endurance; as in endurance resistance training

HR – Heart Rate

MAP – Mean Arterial Pressure

mmHg – Millimeters of Mercury

MVC – Maximal Voluntary Contraction

PP – Aortic Pulse Pressure

PPP – Peripheral Pulse Pressure

PTI – Pressure Time Index

PWV – Pulse Wave Velocity

SBP – Systolic Blood Pressure

SEVR – Subendocardial Viability Ratio

SPSS – Statistical Package for the Social Sciences

USG – Urine Specific Gravity

FILES

1. RECRUITMENT FLYER

Commit To Get Fit!

The Neuromuscular Performance Lab at the University of Texas Rio Grande Valley in Brownsville is recruiting subjects to participate in a training study. :

- **Male subjects between the ages of 50 and 70 years**
- **10 week time commitment**
- **Training 3 times a week**
- **Training Sessions last about 60 minutes**

The purpose of the study is to assess the short-term training effects of low intensity resistance training with and without blood flow restriction on arterial stiffness, hemodynamics, blood oxygen, and vascular resistance.

*** Denotes location of Neuromuscular Performance Lab**

For more information:
Ricardo Parra 956-832-4825
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2. INFORMED CONSENT

The University of Texas Rio Grande Valley

Informed Consent Form

Project Title: The Effects of a Short-Term Resistance Training Program with Blood Flow Restriction Cuffs versus Recommended Resistance Training on Arterial Compliance and Muscular Adaptations in Healthy Middle-aged and Older Males

Principal Investigator: Murat Karabulut Ph.D., CSCS
Co-Investigators: Ulku Karabulut Ph.D.
Research Assistants: Ricardo Parra and Nelson Wise
Department: Health and Human Performance

Background: The purposes of this study are to 1) investigate the short-term training effects on the use of blood flow restriction (BFR) cuffs during resistance training when compared to lower intensity resistance training without BFR on large and small arterial elasticity, and 2) examine how the different resistance training programs, with and without BFR, elicit changes in hemodynamics by measuring resting heart rate (RHR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), cardiac output (CO), stroke volume (SV), systemic vascular resistance (SVR), total vascular impedance (TVI), torque, power, force, and body composition (BC) in recreationally active male subjects.

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

a. This study will take place over the course of 10 weeks.

b. You will be required to visit the research labs in the Department of Health and Human Performance 20 separate days for a total time commitment of about 13 hours.

c. On the first visit (about 60 minutes), you will fill out the health status questionnaire and be familirized with the study procedures. You will also read and sign an informed consent and PAR-Q before any testing takes place. 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.

All study procedures will be conducted in the Exercise Physiology Laboratory (M-1 building, room 216). Time schedules will be agreed on by you and the researcher to when it is most convenient to the subject to be both fasted (for at least 8 hours) and hydrated, 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 will only be required for pre and post testing values.
On the first day, you 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) and familiarization, anthropometric measures that, resting heart rate, blood pressure, height, weight, body composition, and thigh circumference will be performed. Weight and body fat percentage will be measured using the Dxa (Dual-energy X-ray absorptiometry) (. This study will take place over a 10-week period: 8 weeks of resistance training and pre and post testing the week before and after for a total of 10 weeks. Any sessions prior to the beginning of week 2 will be introductory in

1 of 4

nature, including initial paperwork and recording necessary values prior to training. Weeks 2-9 will include the actual training sessions in which each participant will come in and perform the specified routine 3 times a week with at least one day of rest between sessions. Upon finishing the training program, week 10 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, you will perform their 1 repetition maximum of the leg press, leg extension, leg curl, chest press, lat pulldown, and biceps curl (the "exercises") during their first week. Biodex and EMG will then be used in tandem to measure muscle recruitment and strength using a variety of tests (Maximal voluntary contraction, isokinetic repetitions (60&180 deg/s), and Thorstensen). The measurements taken in week 1 will take about 120-180 minutes total (over 2 days).
Measurements in week 1 will be split between 2 days as follows:
Week 1, Day 1: Paperwork, anthropometric measures, one-repetition maximum testing (~60-90 minutes)
Week 1, Day 2: Dxa, Arterial Elasticity, Pulse Wave Analysis, Pulse wave velocity, Electromyography + Biodex (~60-90 minutes).
Weeks 2-7 will include the actual training sessions in which you will come in and perform the specified routine 3 times a week with at least one day of rest between sessions. Depending on which research group you are was randomly assigned to, you will either be performing the designed resistance training program with blood flow restriction or without blood flow restriction or will be in the control group that requires no additional sessions during week 2-9. You will perform these sessions under the supervision of the investigators 3 times a week for 8 weeks in a row for a total of 24 training sessions. The sessions will look as follows:

The Blood Flow restriction group will begin with the subject warming up on the cycle ergometer at 50 rpm and 2.0 kg's resistance. Blood flow restriction cuffs will be applied to the subject's legs and raised to the calculated pressure following established protocol. Subject will then be lead through the resistance-training program that will remain constant for each session thereafter. Subjects will rest 30 seconds between each set. The training routine will consist of 4 sets performed, the first set containing 30 repetitions and the following sets containing 15 repetitions for each of the exercises (all at an intensity of 20-50% of 1 repetition maximum).
The endurance resistance training group will begin with the subject warming up on the cycle ergometer at 50 rpm and 1.0-1.5 kg's resistance. Subject will then be lead through the resistance training program that will remain constant for each session thereafter. Subjects will rest 30 seconds between each set. The training routine will consist 4 sets of 10 repletions of each of the exercises performed at 40-65% of 1 repetition maximum.
The control group will only come to the lab for pre and post-test values and will continue with their normal daily activities. Week 10 will consist of measuring all variables that were recorded in week 1 as outlined above.
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).
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.

Risks or Possible Discomforts Associated with the Study: The study has the following risks:

You understand there are minimal risks to heathy individuals when performing any of the requirements for this project.

Blood Flow Restriction (BFR) cuffs: The minimal risk include discomfort using BFR cuff (for the 30-minute resistance sessions). However, even though these standard protocols have been approved at numerous other institutions and will be performed by qualified and trained personnel.

Body Composition Analysis (DXA scan): You are exposed to radiation on a daily basis, both from natural (sun and earth) and manmade sources. The estimated radiation dose that you will receive as a volunteer for this type of research has been compared to the limits allowed for a radiation worker. This limit is low and is not expected to be harmful. The person obtaining your consent can answer any questions you have, and provide detailed written information about the amount of radiation resulting from this study. If three whole body DXA scans are performed, the estimated radiation dose to the whole body would be 9-12 microsevert (μSv).

Benefits of Participation: 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 cardiovacular health when performing endurance exercise, and arterial health from Pulse Wave Analysis assessment. You will also be given a supervised exercise program.

Voluntary Participation: 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.

Anonymity and/or 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.

Who to Contact for Research Related 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

The University of Texas Rio Grande Valley

Informed Consent Form

investigator Ulku Karabulut at ulku.karabulut@utrgv.edu; the research assistants Ricardo Parra at Ricardo.Parra01@utrgv.edu and Nelson Wise at Nelson.Wise01@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.

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

____ ____/____/______

Participant's Signature Date

Termination of your Participation by the Researcher: If subject misses 3 consecutive sessions, which equals one week of training the subject will automatically be disqualified, and no compensation will be provided.

3. PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

2020 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

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

GENERAL HEALTH QUESTIONS

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

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

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://apps.who.int/iris/handle/10665/44399).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

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

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

NAME ______________________ DATE ______________

SIGNATURE ______________________ WITNESS ______________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________

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

Delay becoming more active if:

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

 1 / 4
01-11-2019

4. HEALTH STATUS QUESTIONNAIRE

University of Texas at Rio Grande Valley

Health Status Questionnaire

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

Part 1. Information About The Individual

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

Part 2. Medical Information

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

14. Last physical fitness test: ____________________(Year)

15. Circle operations you have had:

Back	Heart	Kidney	Eyes	Joint	Neck
Ears	Hernia	Lung	Other__________________________		

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

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

Other____

14. Circle all medicine taken in last 6 months:

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

Other____

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

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

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

1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5

c. Low back pain | f. Chest pain | i. Dizziness

1 2 3 4 5 | 1 2 3 4 5 | 1 2 3 4 5

j. Breathless with slight exertion

1 2 3 4 5

Part 3. Health-Related Behavior

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

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

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

Cigars or pipes only: 5 or more or any inhaled Less than 5, non inhaled

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

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

0 1 2 3 4 5 6 7 days per week

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

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

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

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

____

____

____

5. DATA COLLECTION SHEET

Name: DoB: Pre Date: Height: ______ cm

Post Date. ______ inches

USG: Pre:

Post:

Tanita	Pre		Post	
Total mass	kg	lbs	kg	lbs
Lean mass	kg	lbs	kg	lbs
Fat mass	kg	lbs	kg	lbs
BC:		%		%

SN to Carotid:	mm
SN to Radial:	mm
SN to Femoral:	mm
SN to Ankle:	mm
SN to Cuff:	mm
Femoral to Cuff:	mm

iDexa	Pre		Post	
Total mass	kg	lbs	kg	lbs
Lean mass	kg	lbs	kg	lbs
Fat mass	kg	lbs	kg	lbs
BC:		%		%

Pulse Wave Velocity (Old Sphygmo)

Pre

	1	2	3
C->R			
C->F			
F->D			

Post

	1	2	3
C->R			
C->F			
F->D			

PWA and PWV (New Sphygmo)

Pre:		
HR:		
Period:		
ED:		
T2:		
P1 Height:		
AP:		
AIx - 1:		
AIx - 2:		
AIx - @HR75:		
SEVR:		
PTI - SYS:		
PTI - DIA:		
ESP:		
MAP - SYS:		
MAP - DIA:		
Pf:		
Pb:		
Ref. Magnitude:		
PWV		
PTT:		

Post:	

	Pre				Post		
	1	2	3		1	2	3
MVC				MVC			

ISO 180 **Pre**

2	3	4	5	6	7	8	9	10

Post

2	3	4	5	6	7	8	9	10

ISO 60 **Pre**

2	3	4	5	6	7	8	9	10

Post

2	3	4	5	6	7	8	9	10

Thor **Pre**

1	2	3				48	49	50

Post

1	2	3				48	49	50

BIOGRAPHICAL SKETCH

Ricardo Parra received his BS in Exercise Science in May 2017. He received his MS in Exercise Science in May 2022. Both degrees acquired from The University of Texas Rio Grande Valley in Brownsville, Tx. RicardoParra0100@gmail.com; Ricardo.Parra01@utrgv.edu.