5-2017

Neuromuscular and Arterial Compliance Responses to Different Resistance Training Frequencies and Protocols

Patrick Murphy
The University of Texas Rio Grande Valley

NEUROMUSCULAR AND ARTERIAL COMPLIANCE RESPONSES TO DIFFERENT RESISTANCE TRAINING FREQUENCIES AND PROTOCOLS

A Thesis

by

PATRICK MURPHY

Submitted to the Graduate College of
The University of Texas Rio Grande Valley
In partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2017

Major Subject: Exercise Science

NEUROMUSCULAR AND ARTERIAL COMPLIANCE RESPONSES TO DIFFERENT RESISTANCE TRAINING FREQUENCIES AND PROTOCOLS

A Thesis
by
PATRICK MURPHY

COMMITTEE MEMBERS

Dr. Murat Karabulut
Chair of Committee

Dr. Merrill Funk
Committee Member

Dr. Ryan Russell
Committee Member

May 2017

ABSTRACT

Murphy, Patrick, Neuromuscular and Arterial Compliance Responses to Different Resistance Training Frequencies and Protocols. Master of Science (MS), May, 2017, 124 pp, 1 table, 49 figures, references, 68 titles.

PURPOSE: The purpose of this study was to determine the impact of blood flow restriction and resistance training on arterial elasticity, EMG activity, and strength indices among untrained inactive and recreationally active females who completed 6 weeks of resistance training.

RESULTS: Significant time*condition interactions occurred in LE-1RM ($p<.01$), ISO-60°/s ($p<.05$), FT and ST muscle fiber ($p<.04$). Significant time*reps interactions occurred in VM, RF, VL ISO-60°/s ($p<.05$), and VL Thorstensson ($p<.04$). Significant time main effects occurred in all strength measures ($p<.01$). Repetition main effects occurred in VM, RF, VL ISO-60, and VM, RF, VL Thorstensson ($p<.01$). Significant condition main effects occurred in FT and ST percent change ($p<.03$), and LE-1RM ($p<.01$).

CONCLUSION: All research groups significantly increased all strength and EMG measures, 1X/Week proved significantly better than all groups at increasing 1RM. There were no significant differences in arterial compliance.

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

DEDICATION

The completion of my studies, especially this thesis, would not have been possible without the love and support of my entire family. I would like to dedicate this thesis to my parents, Patrick and Shauna Murphy, and take this chance to express my gratitude for their love, support, and motivation throughout this process. Their unwavering support throughout all my endeavors, for better or for worse, has been and will always be an invaluable asset.

ACKNOWLEDGEMENTS

I am very grateful to all those who have had a firsthand part in the competing of this thesis. I would like to thank my committee, Dr. Karabulut, Dr. Funk, and Dr. Russel, for all their help throughout this process.

I would like to specially acknowledge and thank the chair of the committee, and my mentor, Dr. Karabulut. Two years ago I was about to be a new graduate without a plan, until Dr. K took me under his wing and offered me this tremendous to work for the university and pursue a Master's of Science degree. Along the way I have learned more than I could have imagined and have had a more than worthy example to look to. Dr. K's seemingly tireless work ethic is unmatched in my experience and any and all insight was always welcomed and valuable. From design to pilot testing, data collection to late night statistics, and countless hours and revisions, Dr. K has been everything I could have hoped for in a committee chair, mentor, colleague, and friend.

I would also like to thank my colleagues from UTRGV who have helped along this journey: Especially Danny Dominguez for the many hours spent helping with data collection, excel, data analysis, and writing of this thesis; Brittany Esparza for helping in a crucial part of data collection in pre and post-testing with all female subjects (ie. All of them!), as well as training sessions.

Last but not least, a huge thank you to all my participants for completing my study and making this thesis possible.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of death around the world, and the prevalence of other lifestyle-related diseases like obesity and diabetes is increasing (Arnett et al., 1994; Branca, Nikogosian, & Lobstein, 2007; Fazlioglu et al., 2009; WHO, 2009). These health conditions are influenced by lifestyle behaviors, specifically, physical inactivity has been identified as a central part of the problem (Medicine, 2013; WHO, 2009). ACSM guidelines recommend beginners engage in 3-5 days of aerobic exercise and 2-3 days of resistance exercise for optimal health benefits (2013). These guidelines suggest beginners need to exercise 5 out of 7 of any given week. Such effort is often hard to sustain, and discouraging for beginners to exercise, thereby contributing to the prolonged inactivity (Robison & Rogers, 1994). Adherence has been shown to have a negative relationship with the intensity of the prescribed program, leading to the current recommendations to favor a 7 day per week, or every single day prescription for beginners (Perri et al., 2002; Robison & Rogers, 1994).

With CVD remaining as the number one cause of death globally, and obesity continually rising, it is important to identify programs that promote adherence (Arnett et al., 1994; Fazlioglu et al., 2009; Robison & Rogers, 1994). Evidence suggests that 3 days per week is unnecessary for beginners, and that 1 day or 1 set per week may be adequate to improve health (DeMichele et al., 1997; Graves et al., 1990; DiFrancisco et al., 2007; Taaffe et al., 1999).

Due to its low-intensity nature, blood flow restriction (BFR) training is becoming a popular mode of training, especially in the rehabilitation community (Loenneke et al., 2012). BFR training mimics responses seen with high intensity resistance training, though at much lower intensities, while also showing improvements in arterial compliance (Ozaki et al. 2012; Park, Kwak, Harveson, Weavil, & Seo, 2015). This modality may be ideal for those who have access to it, especially athletes and rehabilitation patients (Abe, Kearns, & Sato, 2006). BFR training involves resistance or bodyweight exercises whilst restricting the blood supply to the active muscle group (Loenneke et al., 2009). A cuff is applied at a calculated pressure in an effort to halt venous return while still allowing arterial flow (Loenneke et al., 2009). The resulting effects including decreased oxygen, increased metabolites and muscle swelling have produced increased muscle hypertrophy, strength and endurance (Loenneke et al. 2012).

Resistance exercise programs of different formats and modalities may allow for a sufficient stimulus needed less often than current recommendations to produce the same health benefits. There is also the possibility of an equal or greater increase in arterial compliance and strength indices when combining BFR and resistance training compared to a higher intensity without BFR. Changes in arterial compliance and strength measures in response to multiple resistance training programs with BFR has yet to be investigated. Therefore, the aim of this study was to investigate the effects of multiple training schemes on arterial compliance and strength indices in a short-term training study, with a focus on modality (BFR versus non-BFR), intensity, volume, and frequency.

Problem and Purpose Statement

Cardiovascular disease and diabetes lead the world in mortality, and are largely controlled by exercise. However, adherence to exercise programs remains a challenge, due in

large part to time constraints. This study aims to investigate the minimum dose of exercise needed to show improvements in arterial elasticity and EMG analysis – an area currently lacking in the literature. To do so, we recruited inactive to recreationally-active females, and asked them to complete 6 weeks of resistance training of different doses, both with and without BFR.

Study Purposes

The Aims of this study were to compare the short-term training effects of various resistance training regimes with and without BFR on: 1) vascular parameters: arterial elasticity, hemodynamics (systolic and diastolic blood pressure, resting heart rate, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, and total vascular resistance); and, 2) indices of strength, such as maximum voluntary contraction, torque, power, force, electromyography, and one-repetition maximum (1RM) in untrained individuals.

Significance of the Study

Resistance training has been established to optimize a number of functions and health indicators, including but not limited to blood pressure, VO_2, body composition, plasma triglycerides, and bone mineral density (Cornelissen et al., 2011; Rhea et al., 2003). Controversy exists in regard to the specifics of an exercise program, like volume, intensity and frequency. It has been shown that as few as 1 session per week can elicit increases in strength and hypertrophy. With today's busy lifestyle, keeping recommendations at two to three days (for beginners) in light of this evidence may be counterproductive.

Blood flow restriction has been shown to replicate the effects of classic resistance training such as strength and hypertrophy, but in less time. One area yet to be explored is the role of BFR in minimizing time spent training. This study would help bridge the gap in the literature

and possibly give way to future training recommendations, especially as BFR technology becomes more available. Examining arterial elasticity and compliance, EMG activity, and strength indices among sedentary and recreationally active individuals in a short-term training study would allow for a comprehensive strength and vascular profile. 6 weeks of traditional resistance, and 1-set circuit-type resistance training has been shown to increase strength similarly (~50%), likely through neuromuscular adaptations rather than muscular hypertrophy (Russell et al., 2015). This study helped provide a better understanding of how BFR affects the cardiovascular system and muscular strength and endurance outcomes, and showed the comparisons between training with BFR versus ACSM protocols. The study further helped determine mechanisms by which vascular restriction produces strength increases by comparing multiple frequencies and schemes.

Assumptions

1. All subjects would adhere to their assigned 6-week training program.
2. All subjects would complete training and tests to the best of their ability.
3. All subjects provided accurate information on Health Status Questionnaire.
4. All equipment used was reliable and provided accurate results following proper calibration.
5. All subjects would not participate in additional physical activity after beginning the study.
6. All subjects arrived 8-hours fasted, hydrated, and rested on pre and post testing days.
7. All participants would complete the study.

Limitations

1. The study may not be representative of the population due to all participants being volunteers rather than randomly sampled.
2. The study was limited to only female volunteers from the Rio Grande Valley area.

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

4. Subjects were requested to maintain their current lifestyle; however, physical activity and nutritional intake outside of the laboratory was not monitored.

Delimitations

1. Individuals with signs or symptoms of CVD were not permitted to participate in the study.
2. Individuals younger than 18 and older than 50 were excluded from this study.
3. Individuals who did not meet the activity and training status criteria were excluded from the study.
4. Individuals were required to be 8-hours fasted and adequately hydrated before testing.
5. Individuals with conditions that prevented maximal testing were excluded.

Research Questions

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

1) Did subjects who were assigned to the BFR group(s) have greater EMG activity?

2) Did subjects who were assigned to the research group(s) perform as good as or better in post-testing than those in the control group?

3) Did BFR result in better arterial elasticity and compliance than control?

Hypotheses

1) BFR group(s) would have greater EMG activity than non-BFR groups.
2) All groups would see statistically significant increases in strength indices. Any differences between groups would not be statistically significant.
3) There would be differences in arterial elasticity and compliance between BFR and non-BFR groups.

Operational Definitions

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

1) **Arterial compliance:** The measurement of the elastic properties of the arteries, which has an inverse relationship with arterial stiffness**.**
2) **Biodex:** Is a device used to measure power, force, moment force (torque), and calculating muscle fiber type percentages.
3) **Blood Flow Restriction (BFR):** BFR is a technique that restricts venous blood return during exercise. This process involves cuffs placed over the inguinal crease, to which they are then inflated to a specific pressure. The cuffs are 5 centimeters wide and contain an inflatable bladder.
4) **Bod Pod:** Gold standard for estimating body fat and fat-free mass using air displacement plethysmography.
5) **EMG:** Measures neural activity in isolated muscles.
6) **Hemodynamics:** Analysis of physical aspects of blood circulation and blood flow.
7) **Hydration:** Hydration status was deemed adequate when urine specific gravity measured 1.010 and lower as determined by a clinical urine refractometer.
8) **PAR-Q:** PAR-Q (Physical activity readiness questionnaire) is a screening tool that is designed to determine whether a subject may perform the exercise in a safe and risk free manner.
9) **Pulse Wave Velocity:** Noninvasive assessment of arterial compliance in which velocity of blood pressure wave forms traveling between two different sites are measured.
10) **Resistance training (RT):** RT refers to the method of training in which muscle(s) work against an external load using a variety of modalities (Aagaard et al., 2002).

Summary

Cardiovascular disease (CVD) remains the leading cause of death around the world with contributing lifestyle-related diseases like obesity and diabetes on the rise (Arnett et al., 1994; Fazlioglu et al., 2009; Branca, Nikogosian, & Lobstein, 2007). Arterial compliance and stiffness are measures regarding the responsiveness and elasticity of arteries that can help identify CVD (Grey et al., 2003). These measures are determined by monitoring the ability of the vessel wall to expand or contract in response to the arterial pulse; stiffening of the arterial network, is related to, and can help predict future cardiovascular disease (CVD) and mortality (Arnett et al., 1994; McEniery, 2006; McEniery et al., 2006; Sugawara, Hayashi, Yokoi, Cortez-Cooper, DeVan, Anton, & Tanaka, 2005). These health conditions are influenced by lifestyle, such as physical inactivity (Medicine, 2013). ACSM guidelines currently recommend 3-5 days of aerobic exercise and 2-3 days of resistance exercise for beginners to receive health benefits (2013).

The current results demonstrated by BFR training prove it to be a viable modality for increasing strength and cannot be ignored as a possible method for more efficient resistance exercise recommendations and prescription in the future (Loenneke et al., 2012). The aforementioned lower intensity training that BFR incorporates will be of great interest and appeal to multiple populations should it be more widely recommended (Loenneke et al., 2012). The current obstacle is the availability of BFR technology as well as evidence that is safe and beneficial practice for all populations.

The Aims of this study were: 1) to investigate the short-term training effects of the use of BFR cuffs during resistance training when compared to recommended protocols without BFR on large and small arterial elasticity; and, 2) to examine how different programming with and

without BFR would cause changes in hemodynamics (resting heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, total vascular impedance), as well as strength indices by measuring maximum voluntary contraction, torque, power, force, electromyography, and one-repetition maximum in untrained individuals.

Chapter 2 contains a literature review on arterial compliance, BFR and resistance training, resistance training volume and frequency, and health and safety concerns. Chapter 3 will be a discussion of the methodology used in the study. In chapter 4, the results are presented and discussed. Chapter 5 then summarizes the study, give conclusions, and suggest future research possibilities.

CHAPTER II

REVIEW OF THE LITERATURE

The Aims of this study were: 1) to investigate the short-term training effects of the use of BFR cuffs during resistance training when compared to recommended protocols without BFR on large and small arterial elasticity; and, 2) to examine how different programming with and without BFR would cause changes in hemodynamics by measuring resting heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, total vascular impedance, as well as strength indices by measuring maximum voluntary contraction, torque, power, force, electromyography, and one-repetition maximum in untrained individuals. Included in this review are the following topics: (1) Arterial Compliance, (2) BFR (BFR) and Resistance Training, (3) Resistance Training Volume and Frequency, (4) Neuromuscular Function, and (5) Health and Safety Concerns.

Arterial Compliance

Arterial compliance is a term that relates to a number of indices regarding the responsiveness and elasticity of arteries, but essentially refers to the ability of the vessel wall to expand or contract passively as pressure changes via systole and diastole (Arnett et al., 1994). A decrease in arterial compliance, and/or an increase in arterial stiffness has been shown to independently predict future CVD and mortality (Arnett et al., 1994; McEniery, 2006; McEniery et al., 2006; Sugawara, Hayashi, Yokoi, Cortez-Cooper, DeVan, Anton, & Tanaka, 2005). CVD still remains the leading cause of death around the world, which encompasses conditions directly

related to arterial compliance and elasticity such as coronary artery disease (Arnett et al., 1994; Fazlioglu et al., 2009). Arterial elasticity and compliance are effective indicators of the health of one's blood vessels, making these indexes valuable to one's health awareness (Tao et al., 2004). Individuals should be proactive as the aging process in associated with changes that relate to decreased compliance and increased stiffness (Hazzouri et al., 2013; Tao et al., 2004). Arterial compliance can be measured noninvasively by using special equipment to determine the pulse wave velocity (PWV) of an individual through measuring time differences of pulse propagations at specific locations on the body, and will provide measures of the stiffness of the arterial walls (Grey et al., 2003; Millasseau et al., 2005).

Arterial compliance and stiffness are fluid properties with extensive research showing their increase or decrease in response to various stimuli. Extensive studies on aerobic exercise training indicate its beneficial role in improving arterial compliance and combatting the effects of aging on the arteries (Cameron & Dart, 1994; Edwards, et. al., 2004; Schjerve et al., 2008). Resistance exercise on the other hand has been shown to increases arterial stiffness and decreases compliance. While RT does have many health benefits, it seems adverse effects on arterial compliance increase with resistance exercise intensity in some (Collier et al., 2008; Fahs et al., 2011; Maeda, 2012; Okamoto, Masuhara, & Ikuta, 2011), but not all studies (Schjerve et al., 2008).

The controversy and lack of evidence in the literature was directly addressed by the present study. This review provides detailed analysis of previous research on BFR and resistance training volumes and frequencies with special attention to arterial compliance.

Blood Flow Restriction and Resistance Training

BFR training mimics beneficial responses seen with high intensity resistance training, though with much lower intensities while also showing improvements in arterial compliance (Ozaki et al. 2012; Park, Kwak, Harveson, Weavil, & Seo, 2015). BFR is a unique technique that involves occluding the venous return from a target muscle group through the use of pressurized pneumatic cuffs (Loenneke, Wilson G., & Wilson J., 2009). The vascular restriction is then achieved through the inflation of these specialized pneumatic cuffs that are wrapped around a target limb and then inflated to a calculated pressure (Loenneke et al., 2012). BFR promotes muscle hypertrophy (Loenneke et al., 2009; Loenneke et al., 2011) at 20% (1 rep-max), which is a much lower intensity than typical resistance training. The lower intensity reduces risk associated with resistance training while offering no additional risk (Loenneke et al., 2011).

As BFR is a relatively new technique, the mechanisms involved, and specific health effects (such as arterial compliance) are still questioned (Loenneke et al., 2011). The proposed mechanisms for hypertrophy are relatively agreed upon and indicate metabolic accumulation is responsible for triggering some anabolic growth factors (Loenneke et al., 2009; Loenneke et al., 2011; Loenneke et al., 2012). This may also cause a larger recruitment of fast twitch muscle fibers and lead to greater protein synthesis (Loenneke et al. 2011; Loenneke et al., 2012). Another more recently proposed and investigated mechanism is the physical muscle swelling caused by pooling during the occlusion, and theoretically this coupled with metabolite accumulation and other proposed mechanisms will yield a greater response (Loenneke et al., 2012).

The lower intensity nature of BFR training makes is particularly suitable for specific populations that may not be able engage in traditional high intensity resistance exercise training,

including the elderly and rehabilitation communities (Loenneke et al., 2012). BFR will appeal to the elderly and recovering athletes who cannot withstand high mechanical stress because it produces positive training adaptations equivalent to those of higher intensities and can achieve rapid results.

Standard resistance training has been the gold standard for increasing muscle size and strength for years, but training incorporating BFR and resistance training, even at a low intensity, may provide greater benefits (Loenneke et al., 2012). BFR paired with low-intensity resistance training (20-30% 1RM) has been shown to increase hypertrophy, strength and endurance equal or greater to that of resistance training (of any intensity) alone (Loenneke et al., 2012). Classic resistance training provides many of the same benefits as BFR training, but has been shown to decrease arterial compliance as intensity increases, whereas BFR training has only been shown to have either no effect, or a positive impact on arterial compliance (Collier et al., 2008; Fahs et al., 2011; Maeda, 2012; Okamoto, Masuhara, & Ikuta, 2011).

While it is clear that there is substantial evidence to support BFR as a training method to increase strength and muscle mass, there are limited data comparing multiple lifting programs simultaneously that incorporate BFR and the effects on arterial compliance as well as strength. The mechanisms remain unclear regarding BFR, RT, and arterial compliance.

Resistance Training Volume and Frequency

The aforementioned epidemic regarding lifestyle-related diseases like CVD and obesity, and their continual rise should incite a sense of urgency to recommend programs more effective at combatting sedentary behavior. Prioritizing program adherence should take priority when prescribing an exercise regime. The ACSM's current guidelines suggests beginners exercise 5 out of 7 days per week, which may not be the most amenable for many beginners. Evidence that

programs with lesser frequency, volume, and ultimately time investment may be just as beneficial as the currently recommended has emerged, but require reinforcement if guidelines are to change (DeMichele et al., 1997; Graves et al., 1990; DiFrancisco et al., 2007; Taaffe et al., 1999).

An important study to be highlighted by Burt, Wilson, and Willardson compared once versus twice-weekly training in untrained women (2007). Each group performed a single set to failure and the resistance was set to allow for 6-10 repetitions, pitting different volumes against each other (Burt, Wilson, & Willardson, 2007). After 8 weeks of training, subjects tested their 6-RM strength again, and found that both groups significantly increased but there were no significant differences between groups ((Burt, Wilson, & Willardson, 2007). This indicates that a single set, once per week (of the leg press) is just as good for strength as twice per week, and that volume was not a factor (Burt, Wilson, & Willardson, 2007).

Another study looked at older adults and compared once versus twice per week strength training (DiFrancisco, Werner, & Douris, 2006). Subjects performed one set to failure either once or twice weekly of three different upper and lower body exercises, comparing the two different volumes (DiFrancisco, Werner, & Douris, 2006). After 9 weeks of training, subjects returned to test 1RM strength and found that both groups significantly increased, but there was no difference between groups (DiFrancisco, Werner, & Douris, 2006). The authors concluded that one set performed once weekly to muscular fatigue improved strength as well as twice weekly in older adults, again demonstrating the unimportance of volume (DiFrancisco, Werner, & Douris, 2006).

A similar study examining older men compared, once, twice, and three times weekly strength training (Taaffe et al., 1999). In this study, older male subjects came in either once,

twice, or three times per week and performed 3 sets of 8 repetitions of 8 different exercises, so again volume was manipulated between groups (Taaffe et al., 1999). After 24 weeks of training, much longer than previous studies, subjects returned for post-testing to find that all groups significantly increased strength and there were no differences between groups (Taaffe et al., 1999). This shows that once or twice weekly achieves the muscle strength increases similar to 3 days per week in older men, and again that volume was not a factor (Taaffe et al., 1999).

Finally, a study that equated for volume compared twice versus three times weekly in untrained men and women (Candow & Burke, 2007). The group that trained twice per week did 3 sets of 10 repetitions to fatigue for 9 exercises, and the group that trained three times per week did 2 sets of 10 repetitions to fatigue for 9 exercises (Candow & Burke, 2007). After training for 6 weeks both groups significantly increased strength measures, but no differences were found between groups (Candow & Burke, 2007). This led to the conclusion that the volume must be more important than the frequency, but did fail to compare against a lower volume group (Candow & Burke, 2007).

The literature available presents some confounding views; in the first few articles presented, volume is not equated but the lower frequency performs just as well, then volume is equated and still the lower frequency group improves just as much. It is important to note that in the studies presented, the population is beginners to resistance training as in the present study.

Neuromuscular Function

In order for muscle contraction to occur an electrical signal must be generated, and not just any signal but one with the amplitude to reach a high enough threshold to initiate the excitation-contraction coupling process that ultimately leads to muscular contraction. The signal created in order to cause contraction can be measured, recorded, and analyzed though the use of

surface electromyography (EMG). EMG allows for the most direct measure, and perhaps gold standard, of neural adaptations, as opposed to standardized tests, balance, strength, coordination, and even bone mineral density (Sale, 1988; Taafe et al., 1999). Capturing and analyzing raw EMG data can allow for some valuable data to be determined. Root mean square (RMS) values of different tests provides the amplitude of the signal in the active muscle, and has been shown to be a good indicator of motor unit recruitment (Suzukie et al., 2002). Median frequency (MDF) is a power value that can be calculated from raw EMG data and has been a reliable indicator of muscular fatigue; as muscle fatigues MDF typically decreases and RMs typically increases (Masuda et al., 1997). The force development or strength of a muscular contraction is not only due the ability of the muscle tissue, these EMG signals that elicit the contraction are plastic and have a synergistic relationship with the muscle itself (Sale, 1988). The relationship between neural adaptation and increased muscle mass on increases in strength has been very well established by the literature.

The manner in which strength gains and increases occur are currently attributed to neural adaptation first and muscular hypertrophy second (Loenneke et al., 2011; Sale, 1988, Taafe et al., 1999). This initial increase in neural adaptation and concurrent increases in strength without demonstrating muscular hypertrophy has been demonstrated consistently in response to traditional resistance exercise training programs (Häkkinen et al., 1985; Sale, 1988). This traditional model may be challenged by different exercise modalities, like BFR resistance exercise, but the literature is lacking the necessary training studies to investigate it.

The present literature demonstrates the need for data on neural adaptations in response to BFR resistance training, and if it is possible should be measured using EMG signals as these values have been presented as the best and most direct measure (Sale, 1988).

Health and Safety Concerns

As BFR emerged as an up and coming technique, the emphasis was placed on what it could do for muscular health and characteristics, but with all exercise and training regimes there are health and safety concerns that should be taken into consideration.

Cardiovascular

There are a few factors to consider here, since the mechanism by which BFR works is squeezing veins and arteries, there may be implications. Peripheral blood flow changes, central responses of the cardiovascular system and blood coagulation should all be considered when applying BFR (Loenneke et al., 2011a).

Oxidative Stress

Oxidative stress can occur under intense training conditions and is characterized by an imbalance between free radicals and antioxidants (Loenneke et al., 2011a). Although this is very rare, it is a factor to consider (Loenneke et al., 2011a).

Muscle Damage

One of the main concerns with the occluding of blood, and along with it, nutrients is the possibility of muscle damage (Loenneke et al., 2011a). Although this is a possibility, there are strict protocols to adhere to when implementing BFR, and if followed properly will not cause harm (Loenneke et al., 2011a).

BFR is an effective tool that can be used to achieve muscular gains, but must also be respected for the risks involved.

Conclusion

In conclusion, the review was able to highlight the efficacy the BFR as a training method for increasing muscle mass and strength as well as outlining the need for more conclusive data on arterial compliance outcomes to resistance training. The literature presented on minimal frequency and volume and frequency training seems quite strong, there just is not a substantial amount of it yet as there should be. Areas that require more exploration is that of the relationship between BFR resistance training, volume, frequency, strength, and neuromuscular adaptations.

Chapter 3 contains a discussion of the methodology used to conduct the present study. In chapter 4, the results of the study are presented and discussed. Chapter 5 contains a summary of the study, conclusions that were drawn, and recommendations for future research related to beginner training programs.

CHAPTER III

METHODS

The Aims of this study were to compare the short-term training effects of various resistance training regimes with and without BFR on: 1) vascular parameters: arterial elasticity, hemodynamics (systolic and diastolic blood pressure, resting heart rate, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, and total vascular resistance); and, 2) indices of strength, such as maximum voluntary contraction, torque, power, force, electromyography, and one-repetition maximum (1RM) in untrained individuals.

Subjects

A total of 46 inactive and recreationally active females between the ages of 18 and 35 participated in the current study. The University of Texas Rio Grande Valley Institutional Review Board approved the study procedure for Human Subjects, and all subjects read and signed an informed consent. Subjects were recruited from the University of Texas Rio Grande Valley campus in Brownsville. Subjects' participation was completely voluntary and were allowed to withdraw at any time without consequence.

Inclusion Criteria

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

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

Exclusion Criteria

1. Participants taking medication for hypertension, cardiovascular disease, or chronic pain.
2. Participants taking medication that may interfere with vascular function.
3. Participants who had joint or muscle problems.
4. Participants whom had a medical history of hypertension, cardiovascular disease, respiratory disease, joint or muscle problems, or any metabolic disease.
5. Participants suffering from chronic back pain and joint injuries in the lower back extremities.
6. Participants who were outside the 18 to 50-year age range.

Recruitment

Participants were recruited from The University of Texas Rio Grande Valley through classroom recruitment in which the professor permission script and in-person script was used. Participants were also recruited by means of fliers and word of mouth at UTRGV. Participation in this study was voluntary and participants were allowed to withdraw at any time.

Experimental Protocol

All study procedures were conducted in the Exercise Science Laboratory (M-1 building, room 216). Time schedules were agreed on by the subject and researcher to when it was most convenient to the subject to be both fasted (for at least 8 hours) and hydrated, for pre and post testing. Hydration was monitored with the use of a urine refractometer, that required the subject

to provide a urine sample to determine the level of current hydration (hydration was at or below 1.010). This study was a total of 8 weeks long with weeks 1 and 8 consisting of pre and post testing and weeks 2- 7 consisting of actual training.

On the first day, the participants filled out questionnaires and were 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 would be excluded from this study. Following initial screening (PAR-Q and health questionnaire, a copy of both forms would be provided) and familiarization, anthropometric measurements included resting heart rate, blood pressure, height, weight, body composition, and thigh circumference. Weight and body fat percentage were measured using the BodPod (gold standard body composition based on air displacement). Thigh circumference was taken at the mid-point of the greater trochanter and lateral epicondyle. Inflation of the BFR cuffs (elastic cuffs that are tightened and filled with air to restrict blood flow) was determined by following the established protocol. Participants also performed a 1RM test to determine future training weight. After anthropometric and body composition measurements were taken, the subject underwent their one-rep max following testing protocol. Heart rate (via Polar chest strap and watch) was monitored continuously during any exercise portion. This first session lasted approximately 35 minutes.

The second day consisted of collecting measurements using SphygmoCor, HDI, BodPod, and Biodex with EMG. These sessions would last for a total of 2 hours. When performing measurements using SphygmoCor the subjects were asked to lie down in the supine position for a minimum of 10 minutes and baseline arterial elasticity and hemodynamics were measured using Hypertension diagnostic (noninvasive equipment conducts measurements of arterial stiffness via placing a sensor on the radial artery at the right wrist and a cuff to the left arm to

measure blood pressure) and measurement of pulse wave velocity using SphygmoCor (which was conducted noninvasively using a pulse wave velocity analyzer in segmental measures at the carotid, femoral, and the dorsalis pedis while wearing three electrodes on the chest to monitor the heart's electrical activity).

Any sessions prior to the beginning of week 2 were introductory in nature, including initial paperwork and recording necessary values prior to training. Weeks 2-7 included the actual training sessions in which each participant came in and performed the specified routine in the exercise science lab using the resistance training machines 1 to 3 times a week, depending on which research group they are placed in, with at least one day of rest between sessions. Upon finishing the 6 week training program, week 8 consisted of measuring all variables that were recorded in week 1. For pre and post recordings subjects were required to be fasted and hydrated prior to testing.

This study consisted of 4 different groups:

A traditional group that trained 3 days a week following standard ACSM resistance training recommendations and guidelines (see appendix)

The high frequency BFR training group trained at 20-50% of their one-rep max 2 times a week (see appendix).

The low frequency to failure BFR training group trained at 20-50% of their one-rep max once a week (see appendix).

The low frequency to failure non-BFR training group trained at 10-20 RM of their one-rep max once a week (see appendix).

All training sessions were performed in the exercise lab using 2 different machines; the leg curl and leg extensions. All training sessions included a 5-minute warm-up on a cycle

ergometer at 1.5 kP and 50 rpm. Each training session in weeks 2-7 took approximately 20 minutes. The time training was a total of 2, 4, or 6 hours for the 6 weeks of training depending on which research group a subject was placed in.

Week 8 consisted of measuring all variables that were recorded in week 1 as outlined above and took the same amount of time.

The minimal risk included discomfort using BFR cuff and performing the one-rep max test (the subject may have felt tired right after the test and sore a day after the test). They were screened in detail before being allowed to participate. If at any time they are unable to complete any task they were allowed to stop.

The research team was required to calibrate all the equipment (which was 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 conducted measurements on the subject of the same gender

Instruments

Clinical Urine Refractometer

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

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

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

Pulse Wave Velocity

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

BodPod

Air displacement plethysmography was used to determine body composition through use of BodPod technology, deemed the Gold standard in the industry. The subjects were required to take off all clothing, jewelry, and shoes before entering the BodPod. The only apparel remaining was compression undergarments and a swim cap to ensure minimize excess volume (ie. Hair) and ensure accurate results.

Delsys Electromyography

Delsys Trigno wireless system was used on subjects when they performed leg extensions on the Biodex. Electrodes were placed on their vastus lateralis, rectus femoris, and vastus medialis. The area were the electrodes were placed was shaved and wiped down with alcohol to ensure proper adhesion to skin and connection to sensors.

Biodex Multi-Joint System – Pro

The Biodex is an apparatus that allows the researcher to measure numerous muscular features (including power, torque, and velocity) for various movements in a controlled setting. The system can be configured in to measure and collect all the required variables being examined. One such test was using the isokinetic dynamometer in which the speed was controlled (60°/s or 180°/s) and the torque would be measured over time. The other test that was used was the maximal voluntary contraction (MVC) which determined the maximum amount of force produced for a single effort, also examined over time.

BFR (blood flow restriction) Cuff

The elastic cuffs are 50 mm in width and were filled with air to create pressure to restrict blood flow. The cuffs were connected to an electronic air pressure control system that monitors

the restrictive pressures. The BFR cuffs were placed on the uppermost portion of the thigh and tightened to the initial pressure. The cuffs were then inflated to reach an individual's final pressure depending on thigh circumference. Inflation began at 120 mmHg and were slowly inflated to a maximal inflation, which was based on the subject's thigh circumference and capillary perfusion. The pressure was slowly increased, by 20 mmHg, by holding the pressure for 30 s and releasing for 10 s between increments until target inflation was reached.

Statistical Analysis

EMGworks Acquisition and Analysis software (2009, Delsys Inc., Boston, MA, USA) was used to capture and analyze raw electrical data. EMG signals were captured and amplified by Trigno Wireless 16 channel EMG system as well as accelerometer information for isokinetic tests. Means were always removed and data that correlated with knee extension tests was isolated. The EMG signals were filtered, via accelerometer data, using a modified bandpass Butterworth filter at 5-500Hz. Mean MDF frequency could then be computed, amplitude analysis and normalization to pre/port MVC required to obtain RMS values.

A 1-way analysis of variance (ANOVA) and analysis of covariance (ANCOVA) with repeated measures was used to see if significant differences existed between groups comparing pre-training and post-training measures in large and small arterial elasticity, central and peripheral pulse wave velocity, blood oxygen level, heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, and total vascular impedance, 1RM, EMG activity, MVC, Thorstensen, and isokinetic torque. A 2-way repeated measures ANOVA was also utilized to analyze EMG amplitude and frequency data captured during isokinetic tests. Bonferroni's post hoc was then employed to further analyze significance of main effects. An alpha of 0.05 was used to determine statistical

significance and data were analyzed using SPSS 23.0 for Windows (IBM Corporation, New York, USA).

CHAPTER IV

RESULTS

The purposes of this study were to 1) determine if subjects who were assigned to the BFR group had greater EMG activity, 2) determine whether or not subjects who were assigned to the lower frequency groups perform better in post-testing than those in the control (traditional) group, and 3) determine if BFR training resulted in better arterial elasticity and compliance than non-BFR resistance training.

Subject Characteristics

Forty-six female subjects were recruited for the study from the University of Texas Rio Grande Valley at the Brownsville campus. Table 1 shows descriptive statistics that were taken from the study population.

Table 1. Descriptive Measures

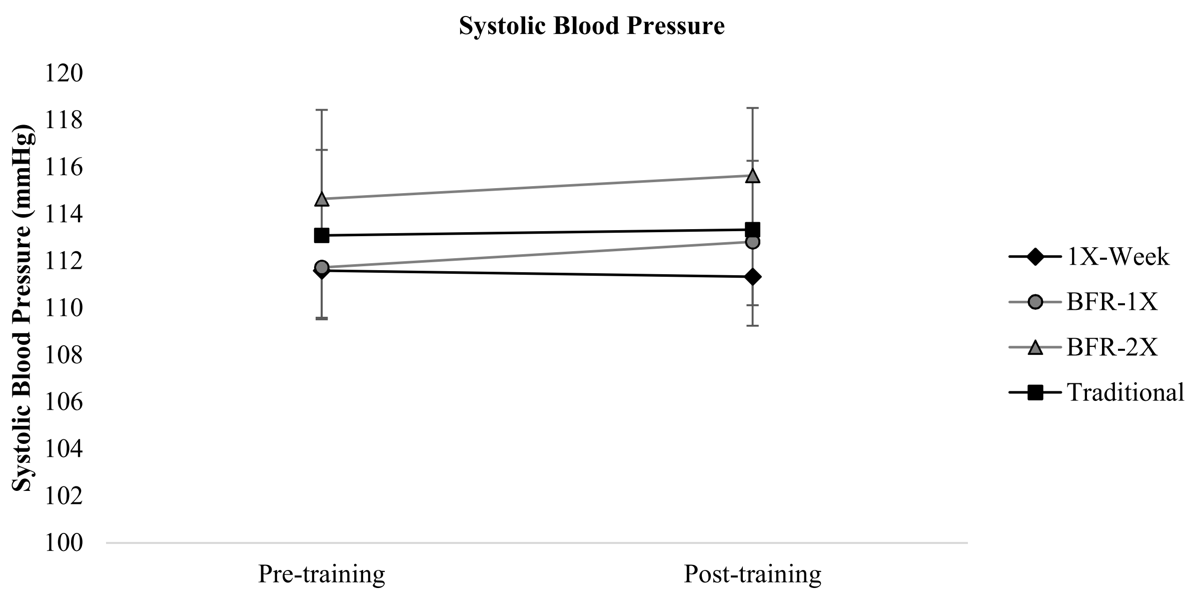
Variables	1x/wk (n=12)	BFR 1x/wk (n=11)	BFR 2x/wk (n=11)	Traditional (n=12)	Combined (n=46)
Age (yr)	23.8 (±4.2)	20.6 (±1.2)	24.2 (±5.7)	22.0 (±3.64)	22.7 (±4.1)
Height (cm)	159.9 (±4.4)	161.4 (±5.2)	157.1 (±5.2)	159.6 (±5.1)	159.5 (±5.1)
Weight (kg)	74.1 (±26.0)	65.9 (±13.8)	63.5 (±10.3)	67.0 (±14.2)	67.7 (±17.2)
BMI (kg/m^2)	28.6 (±8.7)	25.3 (±5.0)	25.7 (±4.0)	26.3 (±5.2)	26.5 (±6.0)

Values are reported as means (±SD).

Hemodynamic Responses

Figure 1 shows the effects the 4 different conditions had on SBP after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

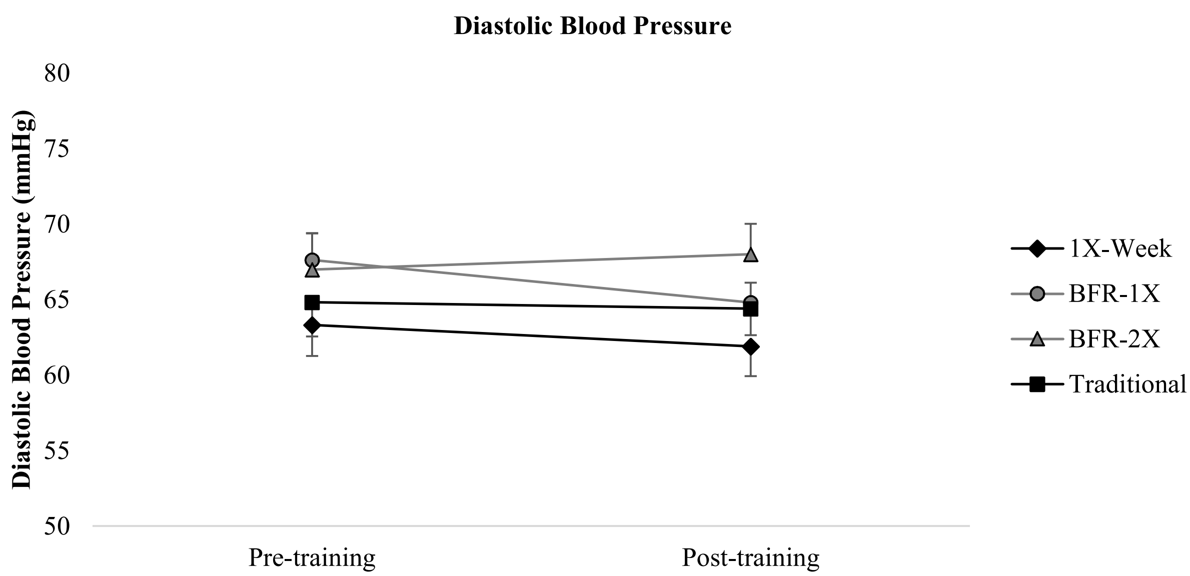
Figure 1. Systolic Blood Pressure



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 2 shows the effects the 4 different conditions had on DBP after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

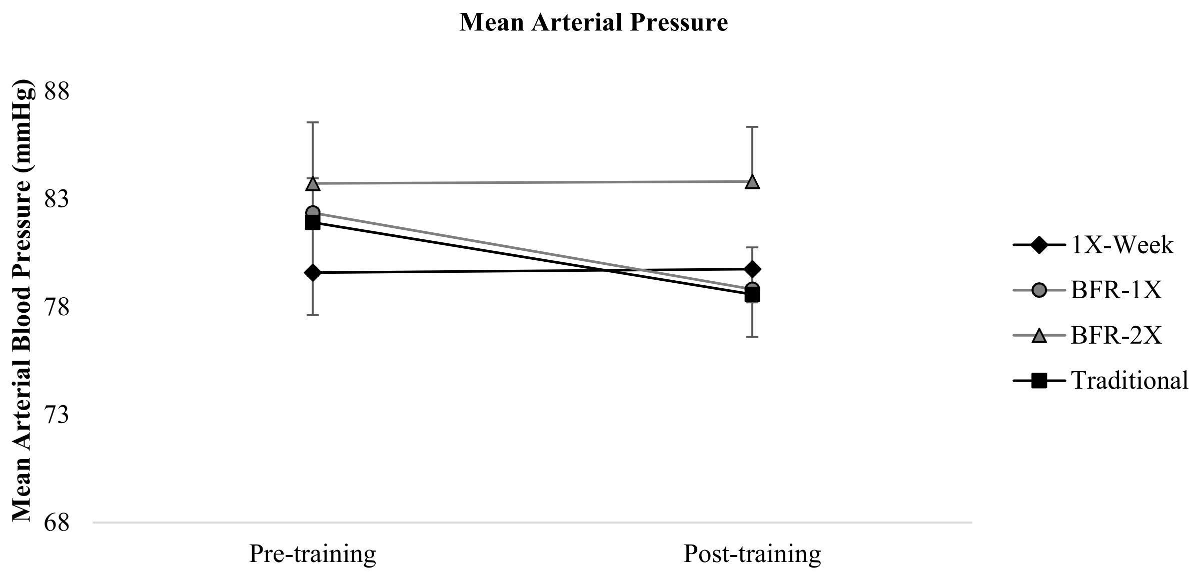
Figure 2. Diastolic Blood Pressure



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 3 shows the effects the 4 different conditions had on mean arterial blood pressure after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

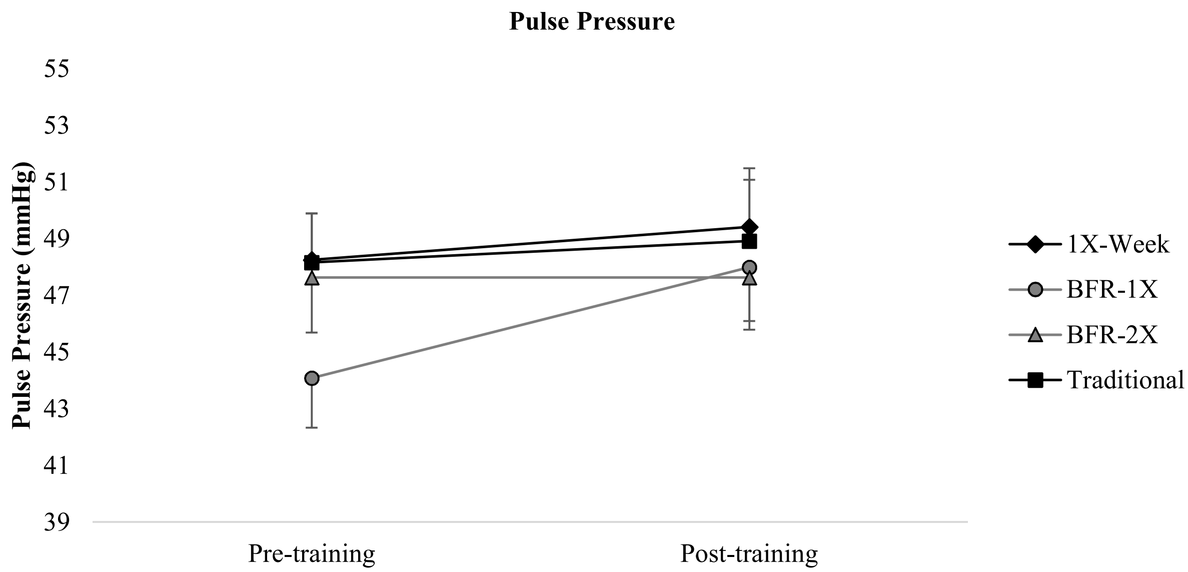
Figure 3. Mean Arterial Pressure



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 4 shows the effects the 4 different conditions had on PP after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

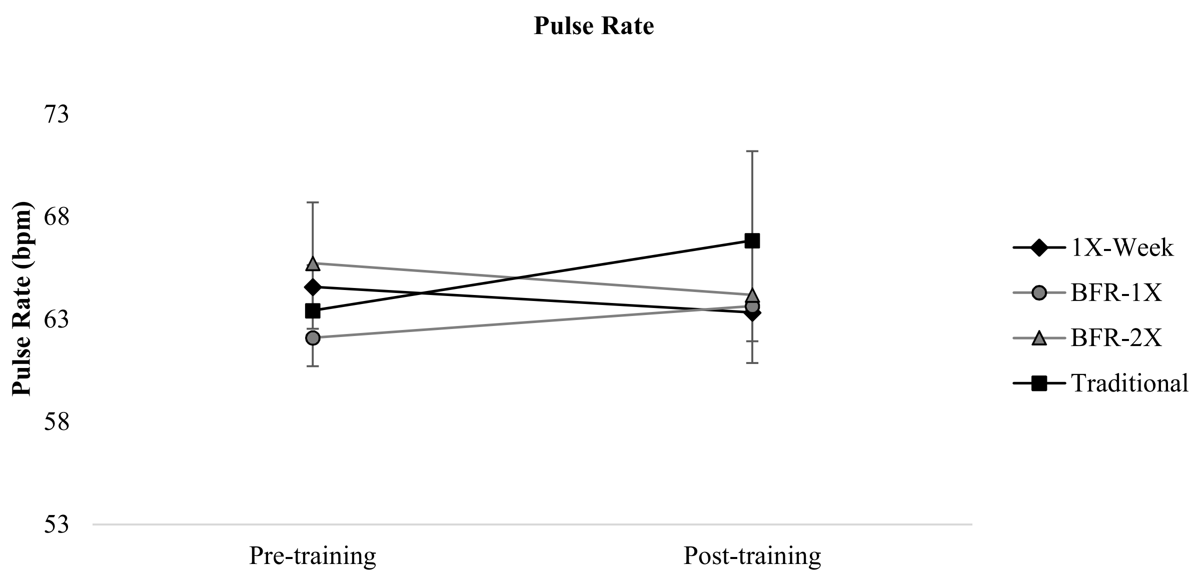
Figure 4. Pulse Pressure



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 5 shows the effects the 4 different conditions had on PR after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

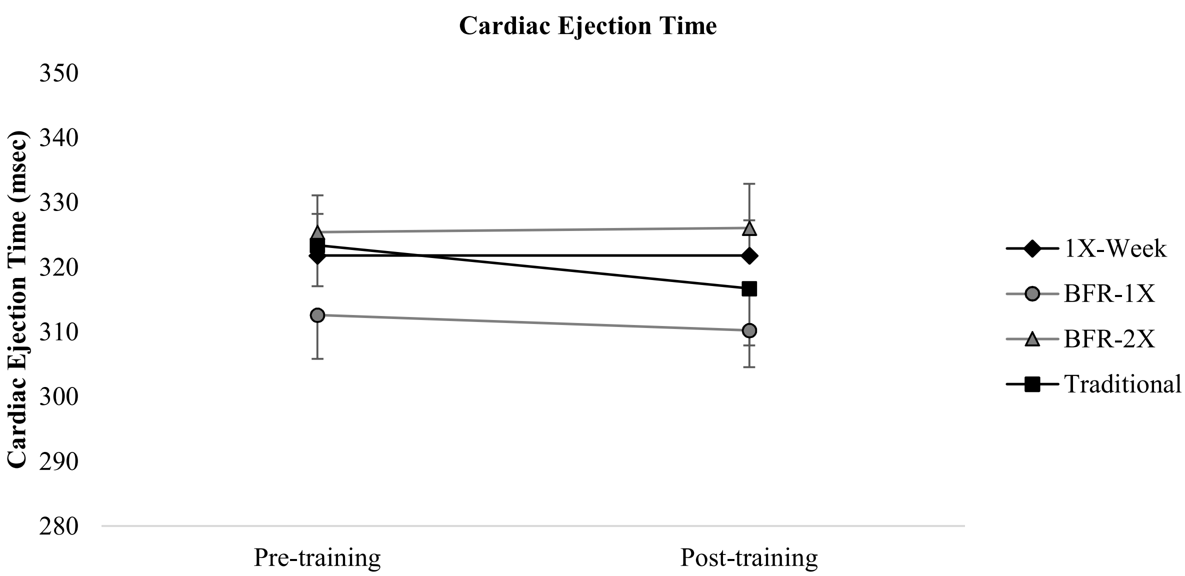
Figure 5. Pulse Rate



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 6 shows the effects the 4 different conditions had on CET after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

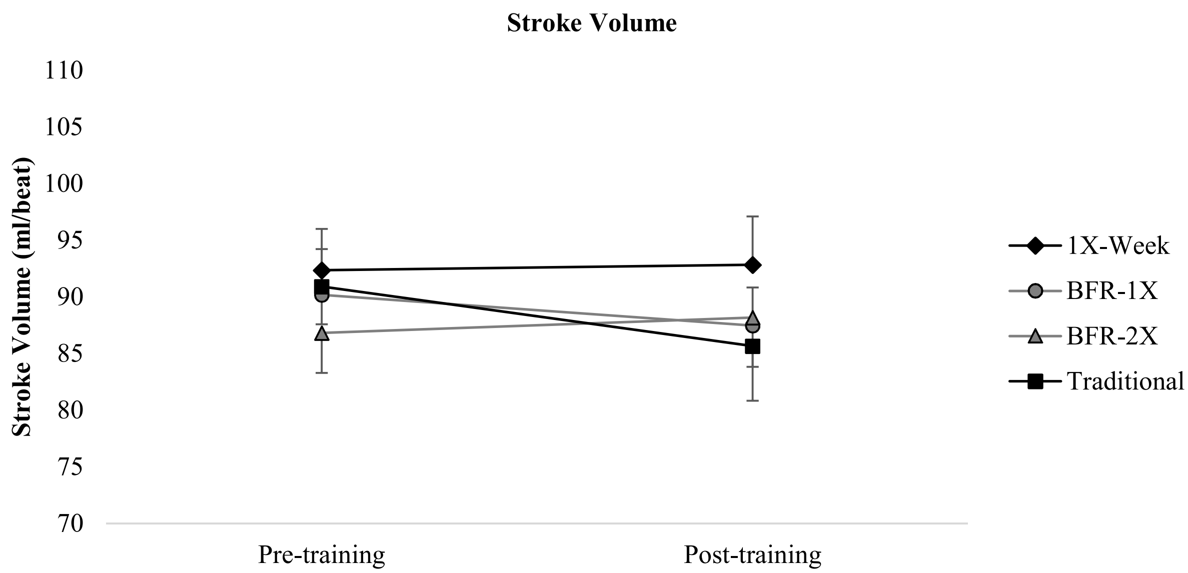
Figure 6. Cardiac Ejection Time



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 7 shows the effects the 4 different conditions had on SV after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

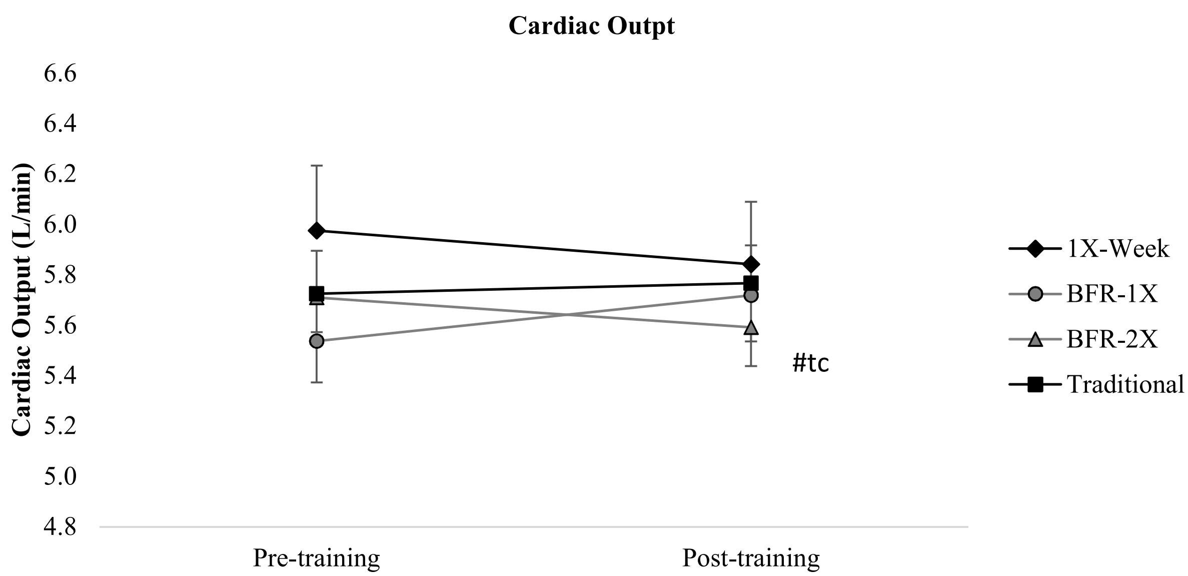
Figure 7. Stroke Volume



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 8 shows the effects the 4 different conditions had on CO after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. Repeated measures showed a trend for time*condition interaction (p = 0.089). All categories were not statistically different (p > 0.05) for all condition and time main effects and interactions and they were reported together.

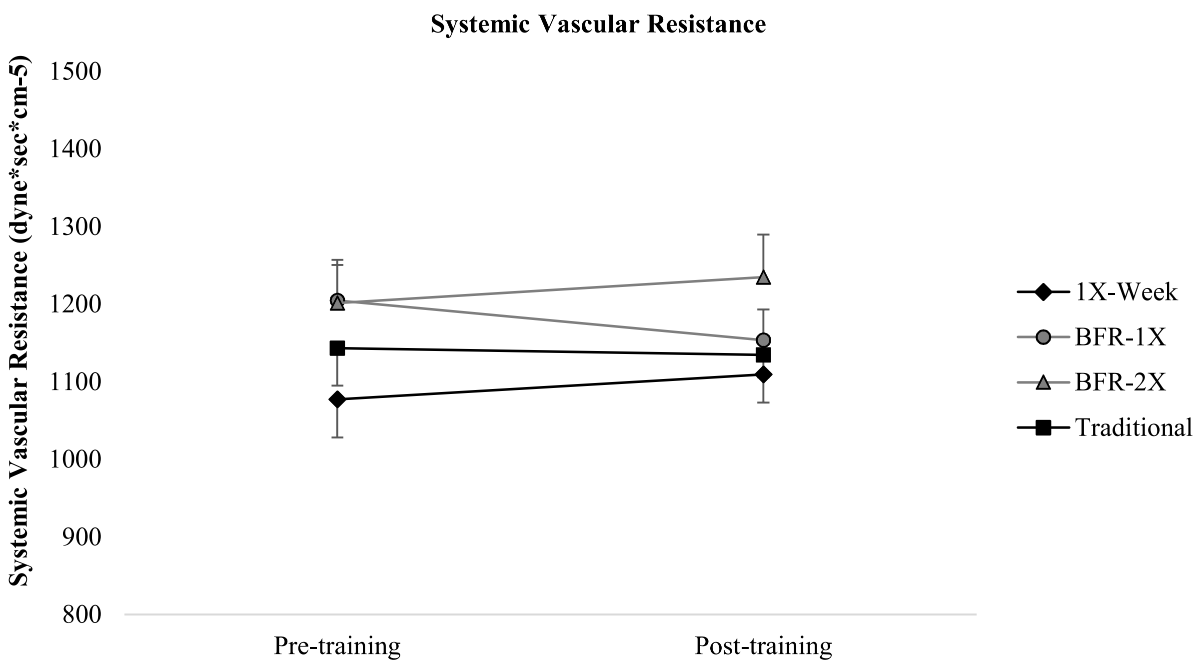
Figure 8. Cardiac Output



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
#tc Trend time*condition interaction (p=.089). Values reported as mean ±SE.

Figure 9 shows the effects the 4 different conditions had on SVR after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

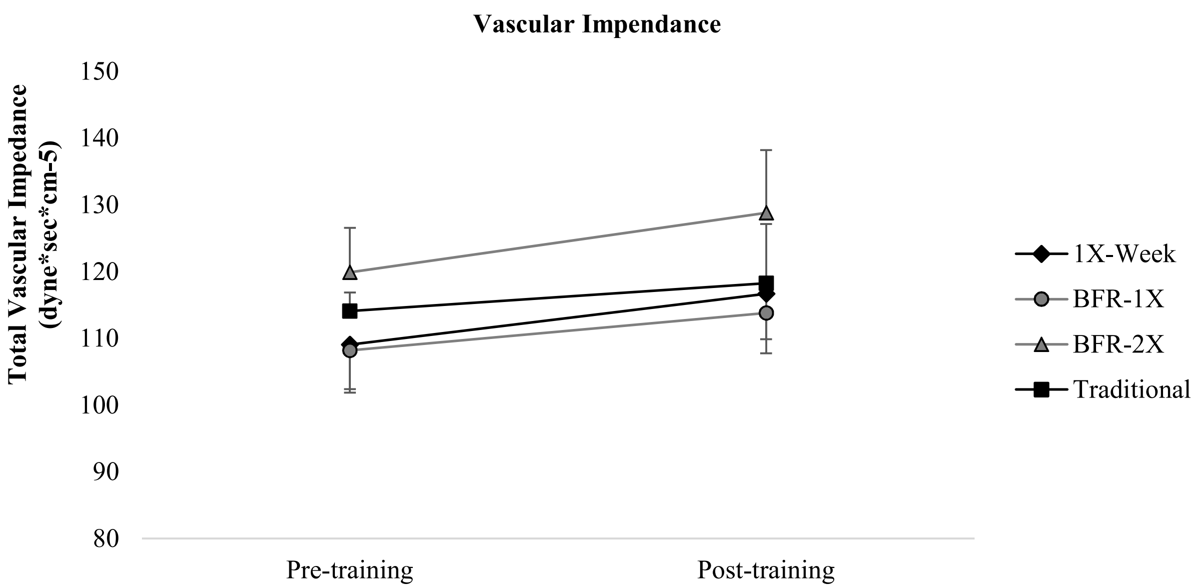
Figure 9. Systemic Vascular Resistance



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 10 shows the effects the 4 different conditions had on VI after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

Figure 10. Total Vascular Impedance

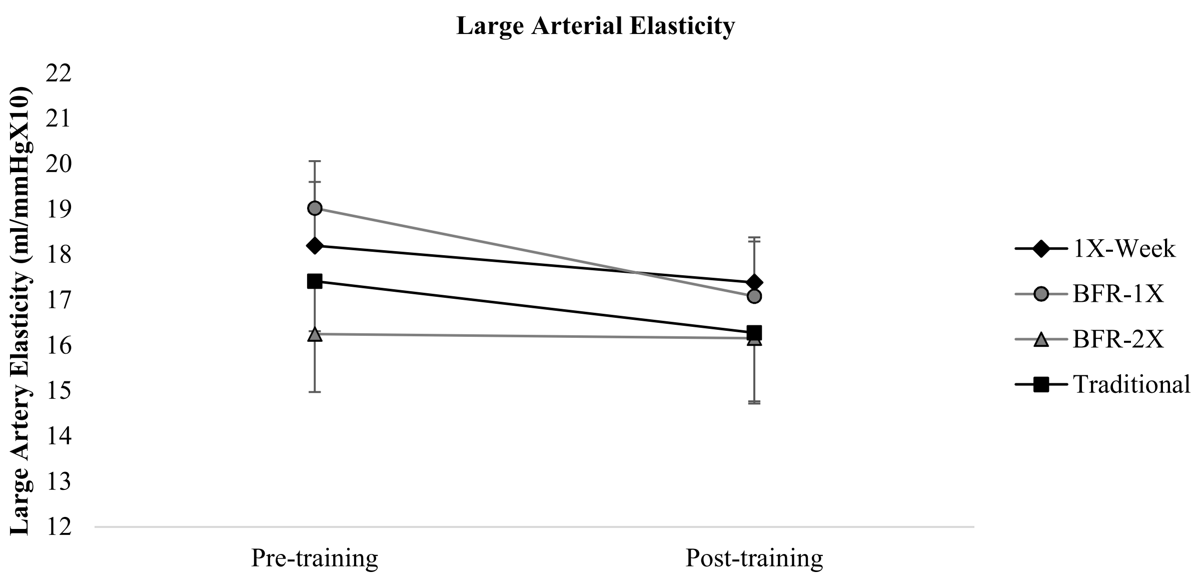


1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Arterial Compliance

Figure 11 shows the effects the 4 different conditions had on LAE after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

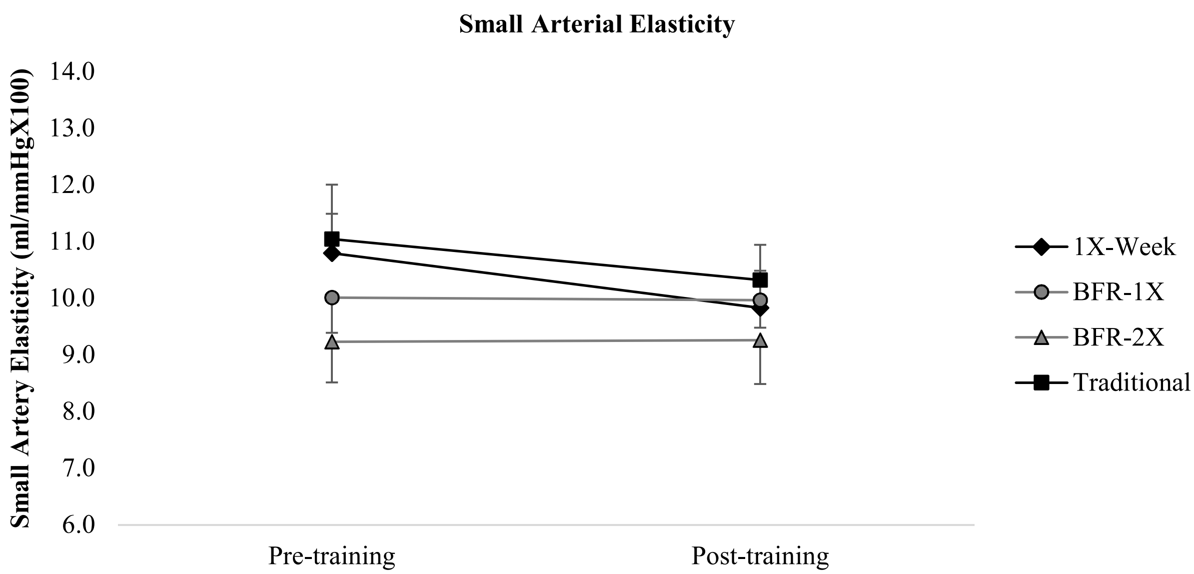
Figure 11. Large Arterial Elasticity



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 12 shows the effects the 4 different conditions had on SAE after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

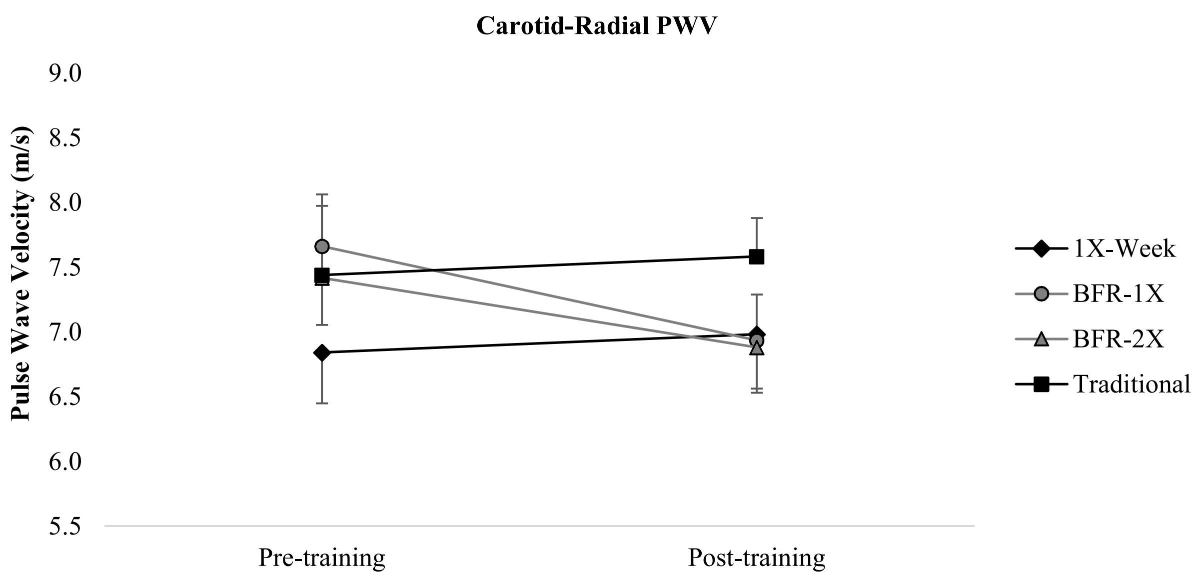
Figure 12. Small Arterial Elasticity



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 13 shows the effects the 4 different conditions had on PWV from the carotid to radial artery after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

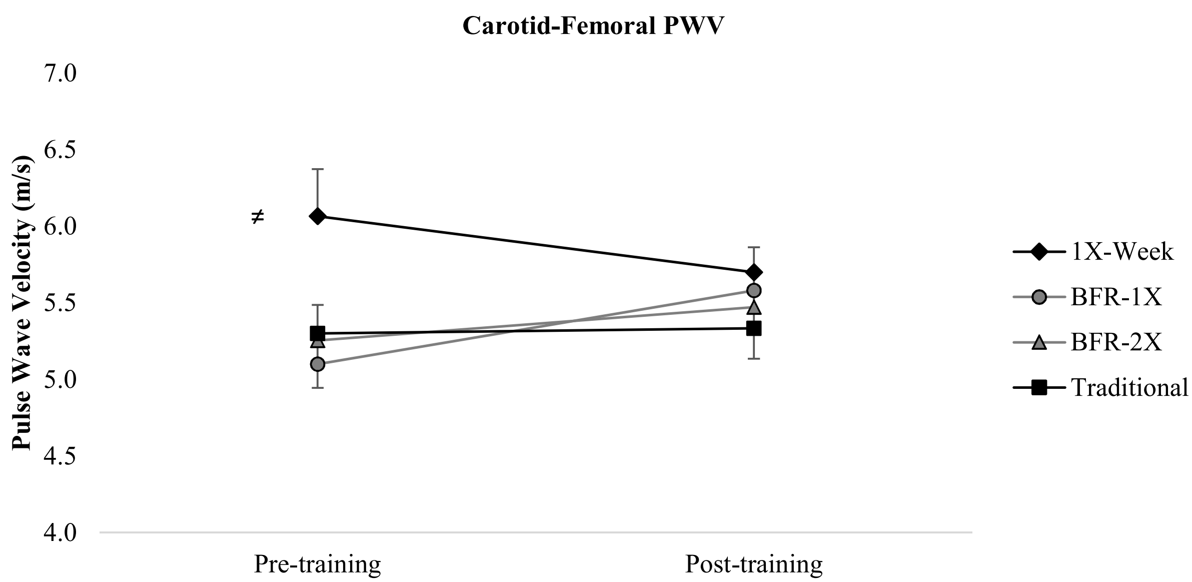
Figure 13. PWV Carotid to Radial



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 14 shows the effects the 4 different conditions had on PWV form the carotid to femoral artery after the 6-week training period. ANCOVA detected baseline differences between groups and homogeneity of variances assumption was refuted by Levene's test (p = 0.019). One-way ANOVA did not detect between-group differences at baseline. All categories were not statistically different (p > 0.05) for all condition and time main effects and interactions and they were reported together.

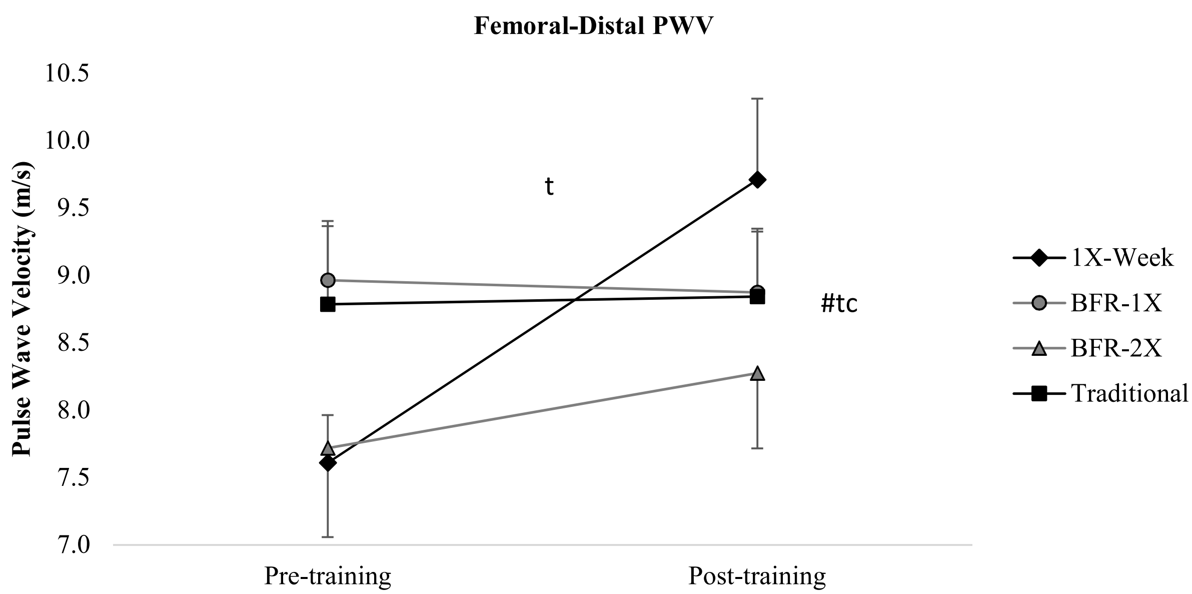
Figure 14. PWV Carotid to Femoral



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
≠ Significant condition baseline difference (p=0.019). Values reported as mean ±SE.

Figure 15 shows the effects the 4 different conditions had on PWV from the femoral to distal artery after the 6-week training period. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA trend for time*condition ($p = 0.08$) interaction and time ($p = 0.052$) main effect. Time main effect showed a trend for an increase of PWV from the femoral to distal artery in all conditions.

Figure 15. PWV Femoral to Distal

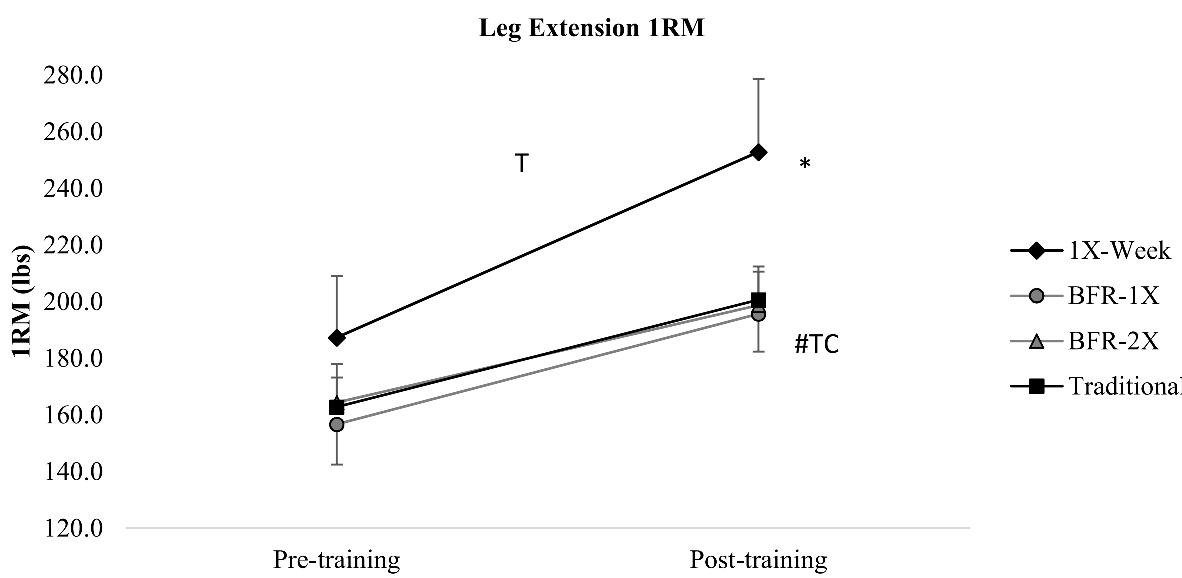


1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
t Trend for time difference (p=.052). #tc Trend for time*condition interaction (p=.08). Values reported as mean ±SE.

Strength Measures

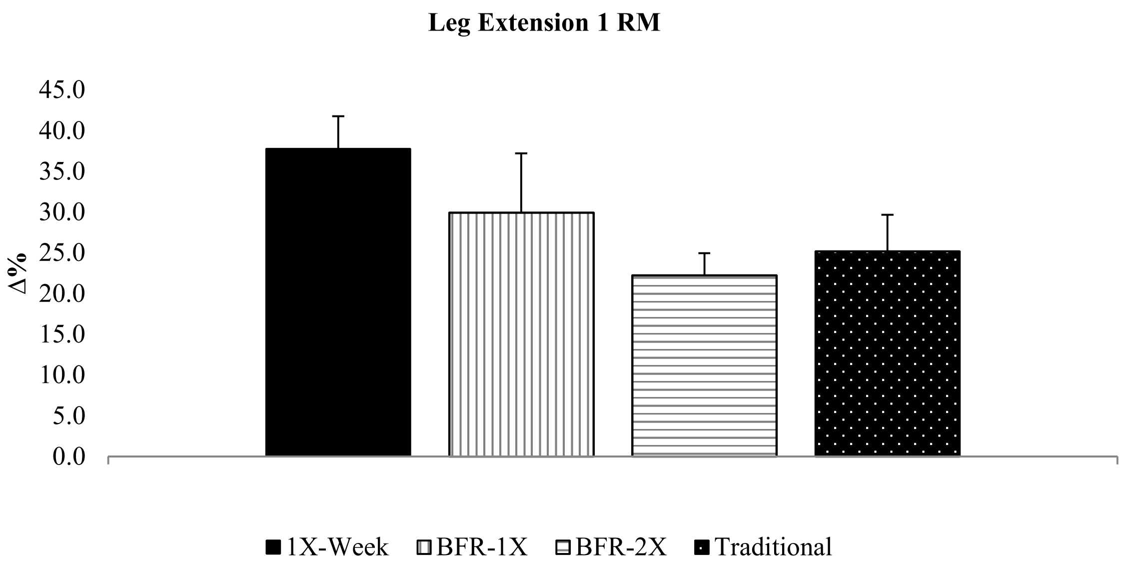
Figure 16 shows the effects the 4 different conditions had on LE-1RM after the 6-week training period and Figure 16A shows corresponding percent change in LE-1RM for each condition. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. ANCOVA found a significant condition main effect (p < 0.01). Condition main effect showed that 1X-Week increase in LE-1RM was significantly greater than all other conditions. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA also showed a significant interaction for time*condition (p < 0.01) and time (p < 0.01) main effect. For time main effect, post-training LE-1RM was significantly greater than pre-training in all conditions.

Figure 16. Leg Extension 1RM



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
* Significant condition difference (p<.01). T Significant time difference (*p*<.01). #TC Significant time*condition interaction (p<.01). Values reported as mean ±SE.

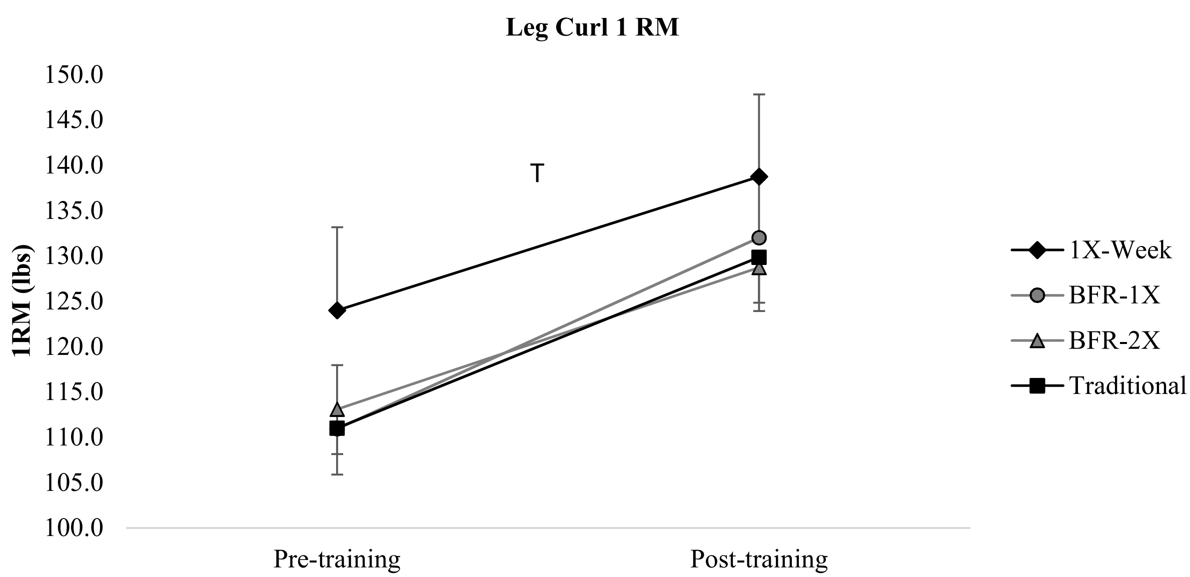
Figure 16A. Leg Extension 1RM % Change



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

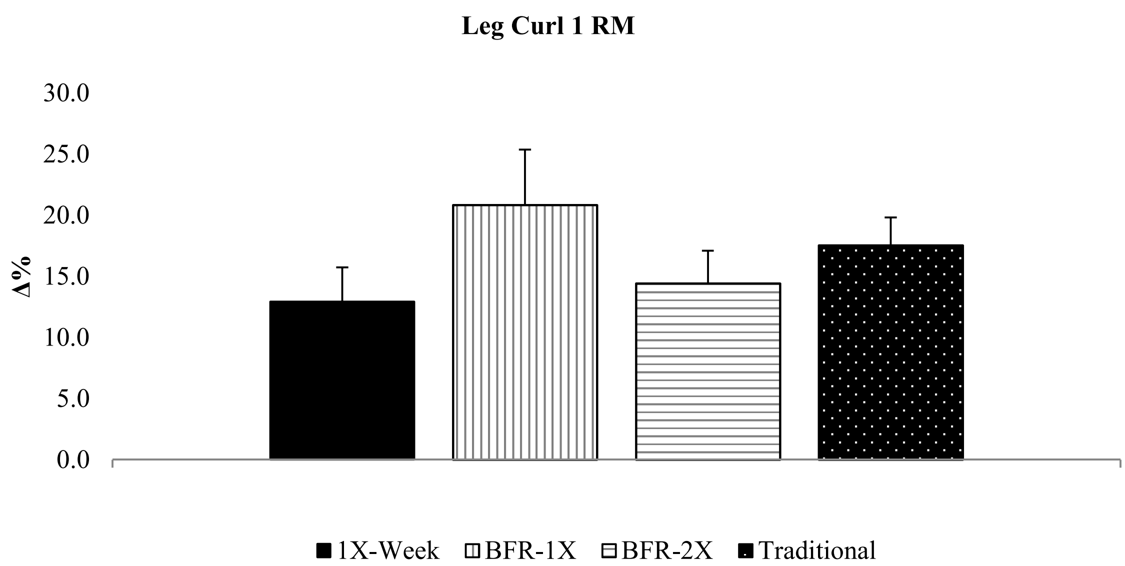
Figure 17 shows the effects the 4 different conditions had on LC-1RM after the 6-week training period and Figure 17A shows corresponding percent change in LC-1RM for each condition. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant time main effect ($p < 0.01$). For time main effect, post-training LC-1RM was significantly greater than pre-training in all conditions.

Figure 17. Leg Curl 1RM



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (*p*<.01). Values reported as mean ±SE.

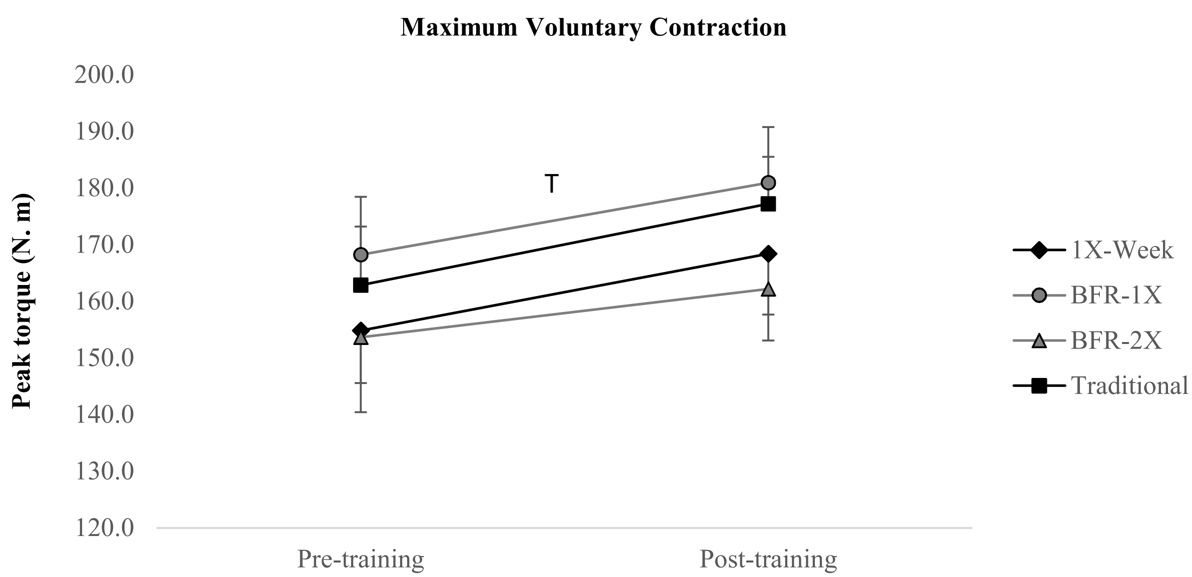
Figure 17A. Leg Curl 1RM % Change



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

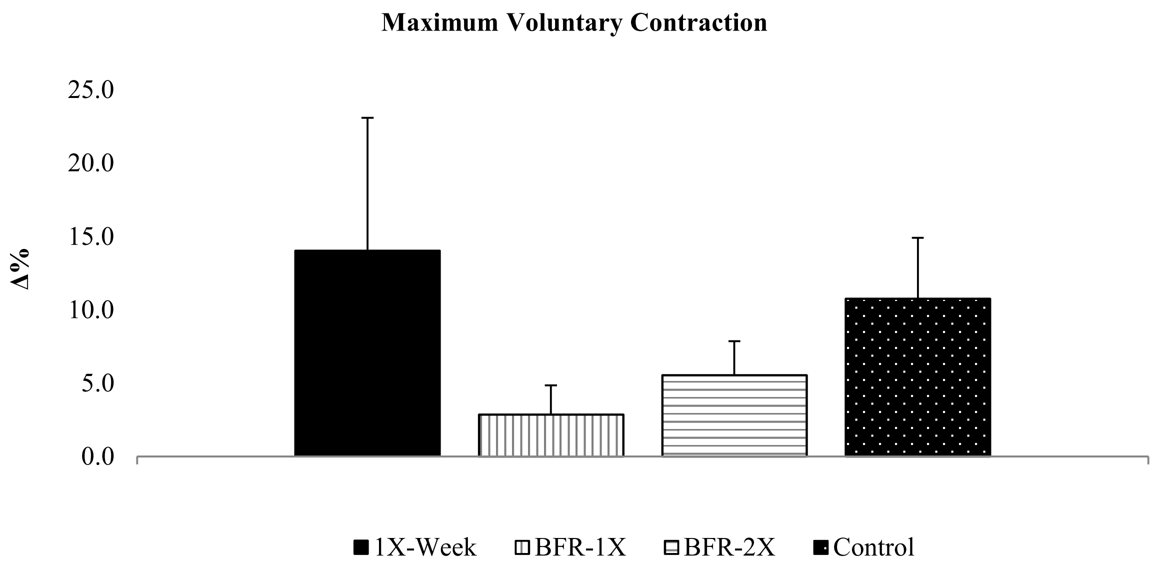
Figure 18 shows the effects the 4 different conditions had on MVC after the 6-week training period and Figure 18A shows corresponding percent change in MVC for each condition. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant time main effect ($p < 0.01$). For time main effect, post-training MVC was significantly greater than pre-training in all conditions.

Figure 18. Maximum Voluntary Contraction



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.01). Values reported as mean ±SE.

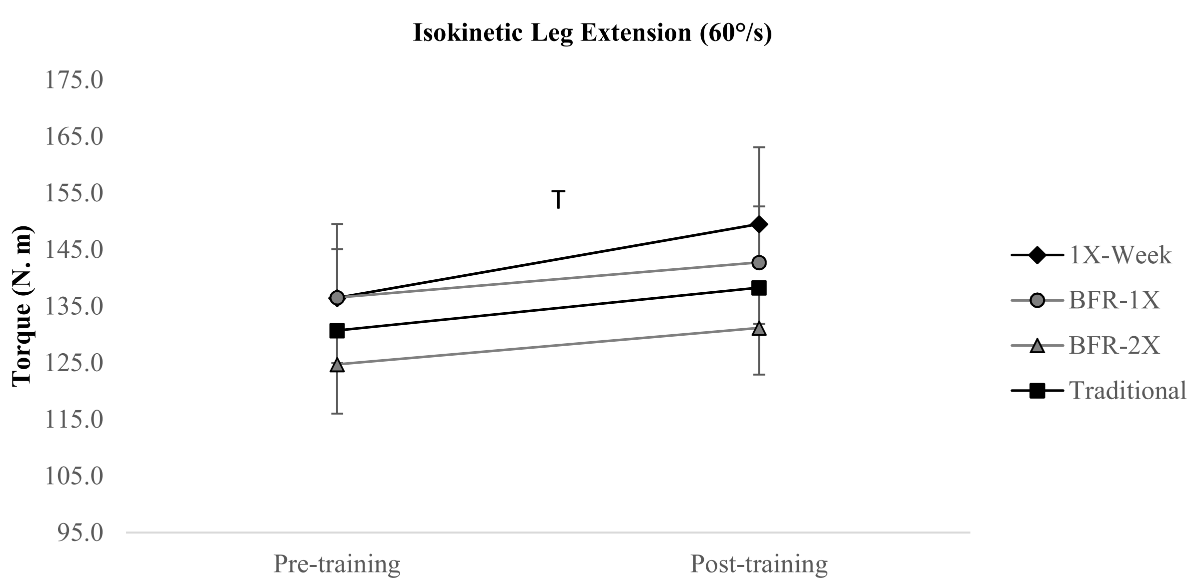
Figure 18A. Maximum Voluntary Contraction % Change



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

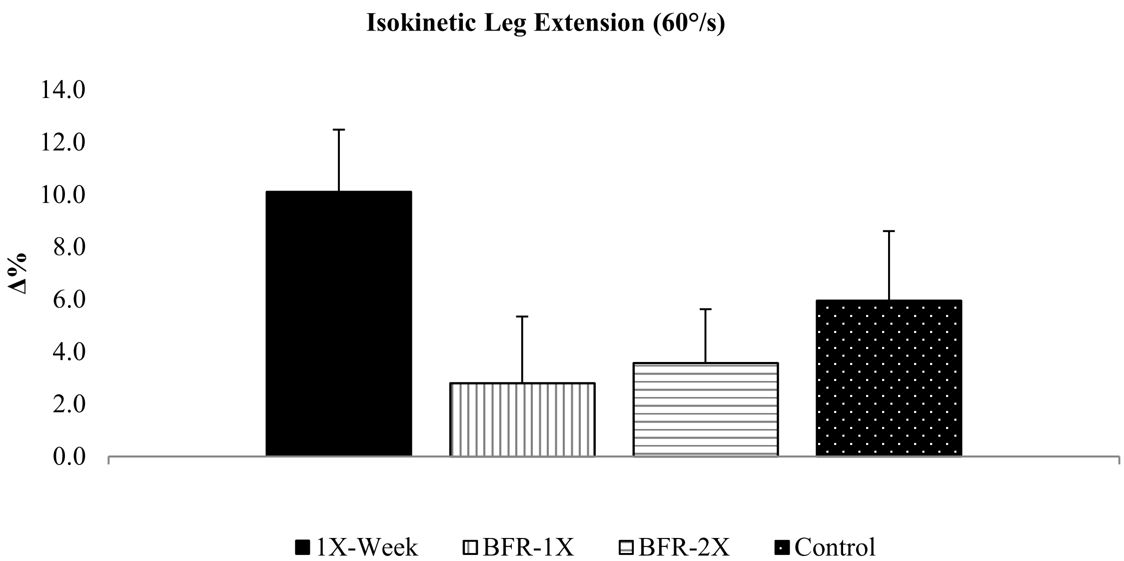
Figure 19 shows the effects the 4 different conditions had on ISO-60°/s leg extensor torque after the 6-week training period and Figure 19A shows corresponding percent change in ISO-60°/s for all conditions. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. ANCOVA found significant condition main effect ($p < 0.05$). Condition main effect showed that 1X-Week increase in ISO-60°/s leg extensor torque was significantly greater than BFR-1X. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant interaction for time*condition ($p < 0.05$), time ($p < 0.01$) main effect and a trend for condition ($p = 0.06$) main effect. For time main effect, post-training ISO-60°/s leg extensor torque was significantly greater than pre-training in all conditions.

Figure 19. Isokinetic Leg Extension (60°/s)



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (*p*<.01). Values reported as mean ±SE.

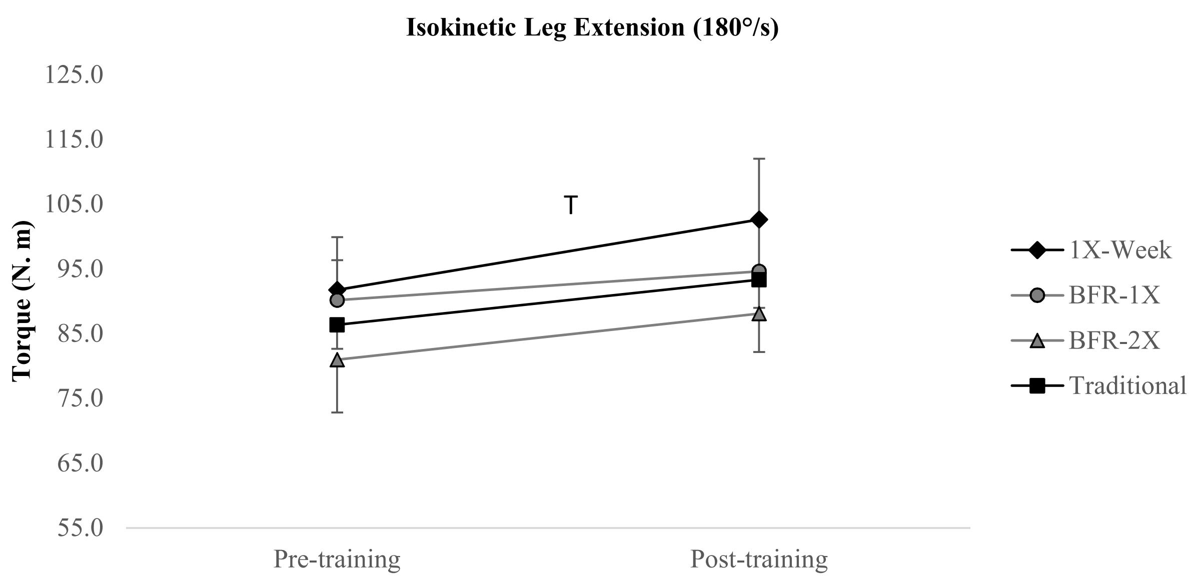
Figure 19A. Isokinetic Leg Extension (60°/s) % Change



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

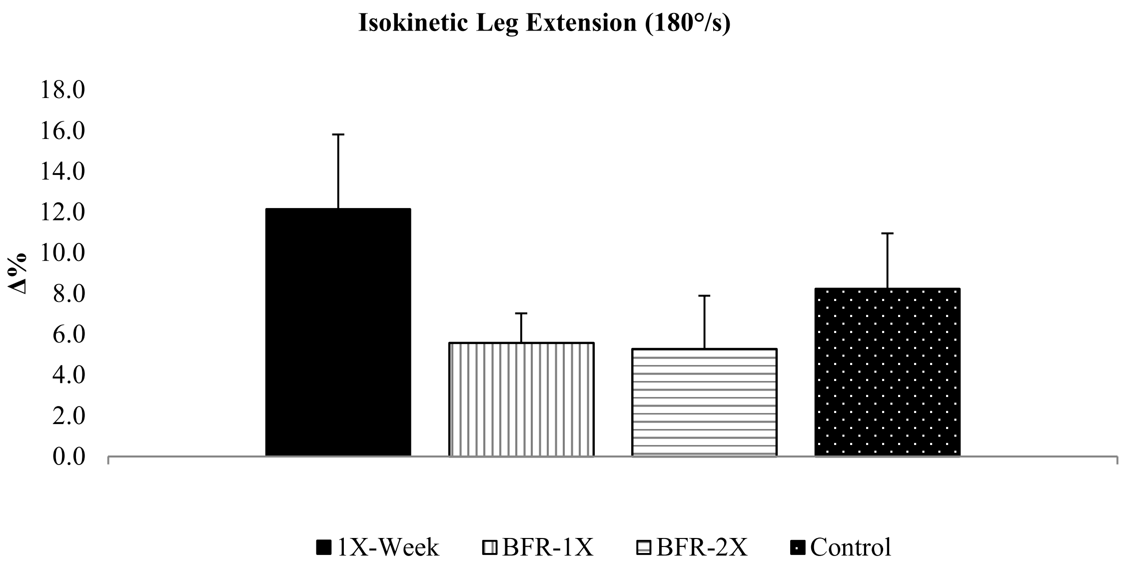
Figure 20 shows the effects the 4 different conditions had on ISO-180°/s leg extensor torque after the 6-week training period and Figure 22A shows corresponding percent change in ISO-180°/s leg extensor torque. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene’s test of equality and variance. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant time main effect ($p < 0.01$). For time main effect, post-training ISO-180°/s leg extensor torque was significantly greater than pre-training in all conditions.

Figure 20. Isokinetic Leg Extension (180°/s)



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (*p*<.01). Values reported as mean ±SE.

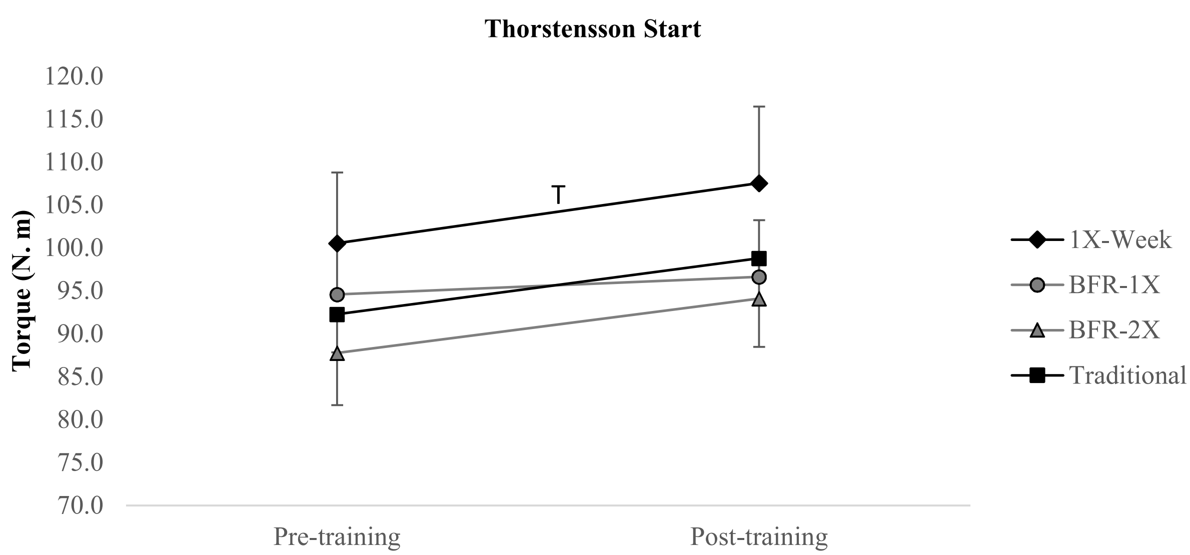
Figure 20A. Isokinetic Leg Extension (180°/s) % Change



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

Figure 21 shows the effects the 4 different conditions had on Thorstensson start 180°/s leg extensor torque after the 6-week training period and Figure 23A shows corresponding percent change in Thorstensson start 180°/s leg extensor torque for all conditions. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant time main effect ($p < 0.01$). For time main effect, post-training Thorstensson start 180°/s leg extensor torque was significantly greater than pre-training in all conditions.

Figure 21. Thorstensson Initial Strength



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.01). Values reported as mean ±SE.

Figure 22 shows the effects the 4 different conditions had on Thorstensson mid 180°/s leg extensor torque after the 6-week training period and Figure 23A shows corresponding percent change in Thorstensson mid 180°/s leg extensor torque for all conditions. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant time main effect ($p < 0.01$). For time main effect, post-training Thorstensson mid 180°/s leg extensor torque was significantly greater than pre-training in all conditions.

Figure 22. Thorstensson Mid Strength

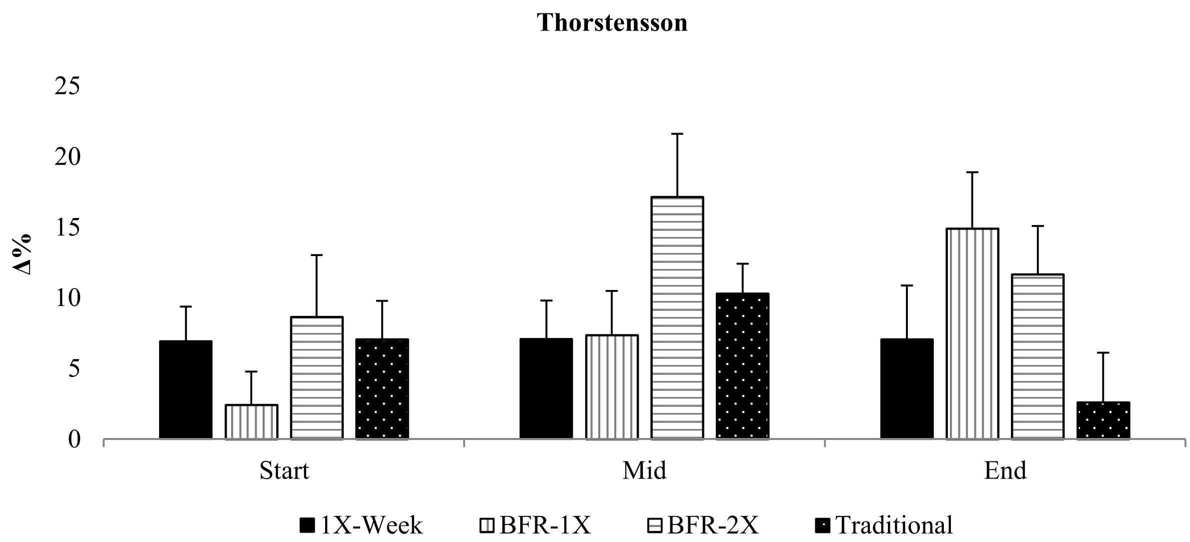
1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference ($p<.01$). Values reported as mean ±SE.

Figure 23 shows the effects the 4 different conditions had on Thorstensson end 180°/s leg extensor torque after the 6-week training period and Figure 23A shows corresponding percent change in Thorstensson end 180°/s leg extensor torque for all conditions. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant time main effect ($p < 0.01$). For time main effect, post-training Thorstensson end 180°/s leg extensor torque was significantly greater than pre-training in all conditions.

Figure 23. Thorstensson End Strength

1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (*p*<.01). Values reported as mean ±SE.

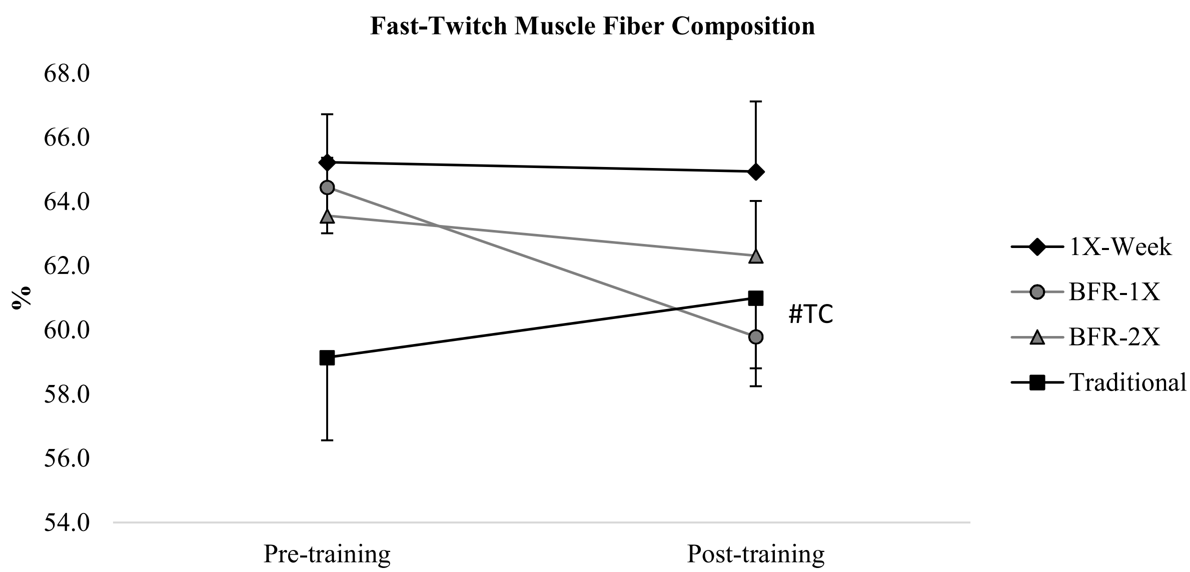
Figure 23A. Thorstensson Strength % Changes



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE.

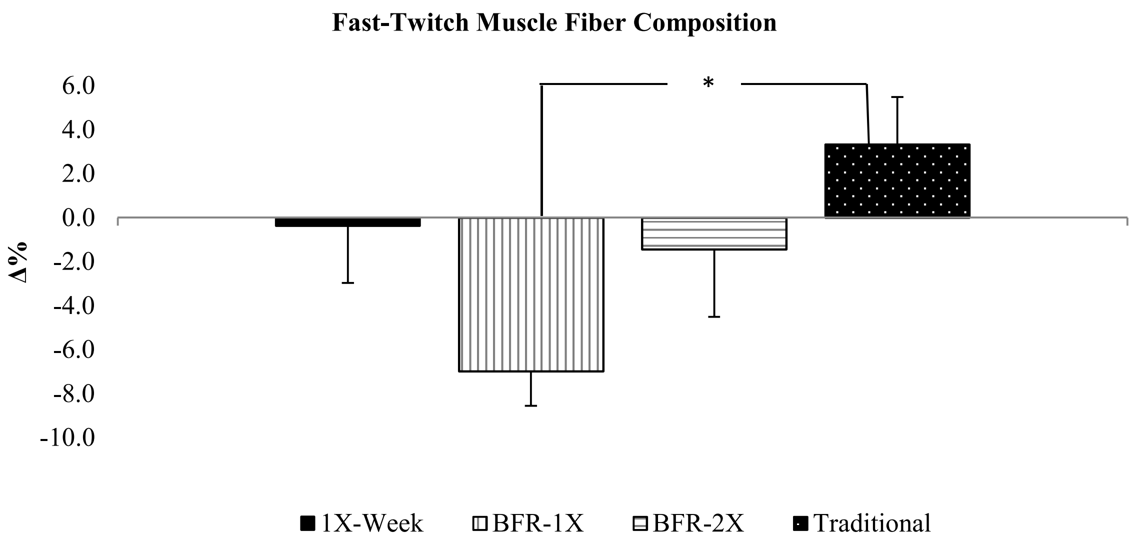
Figure 24 shows the effects the 4 different conditions had on FT muscle fiber composition after the 6-week training period and Figure 24A shows corresponding percent change in FT muscle fiber composition for all conditions. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. ANCOVA found a trend for condition main effect ($p = 0.08$). Follow-up pairwise comparison washed out the trend. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant interaction for time*condition ($p < 0.04$) and a significant condition ($p < 0.04$) main effect. For condition main effect, Traditional percent change in FT muscle fiber composition was significantly greater than BFR-1X.

Figure 24. Fast Twitch Muscle Fiber Composition



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
#TC Significant time*condition interaction (p<.04). Values reported as mean ±SE.

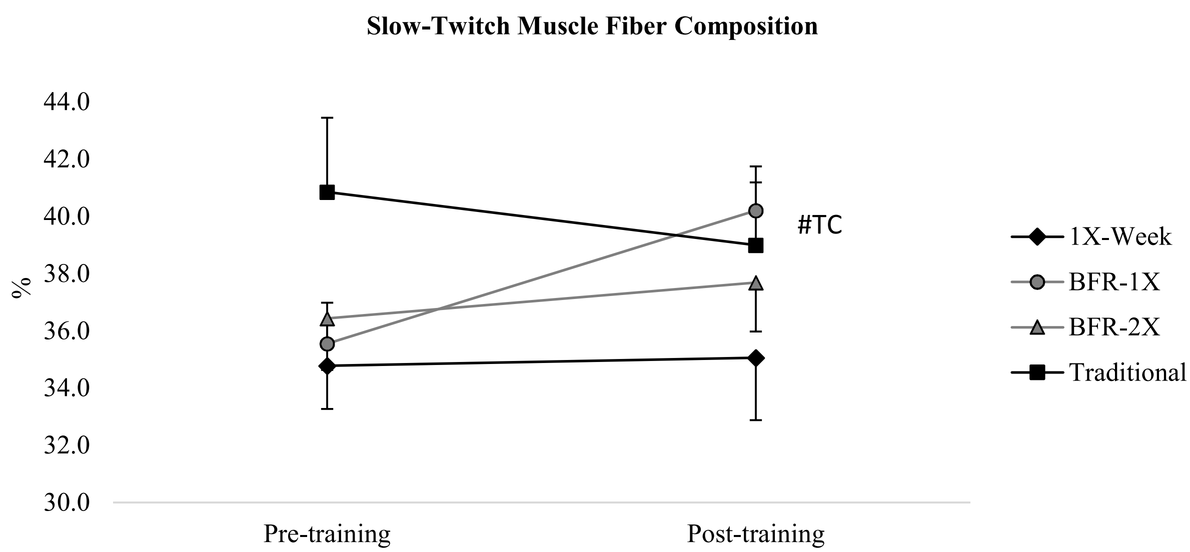
Figure 24A. Percent Change in Fast Twitch Muscle Fiber Composition



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
* Significant condition difference (p<.04). Values reported as mean ±SE.

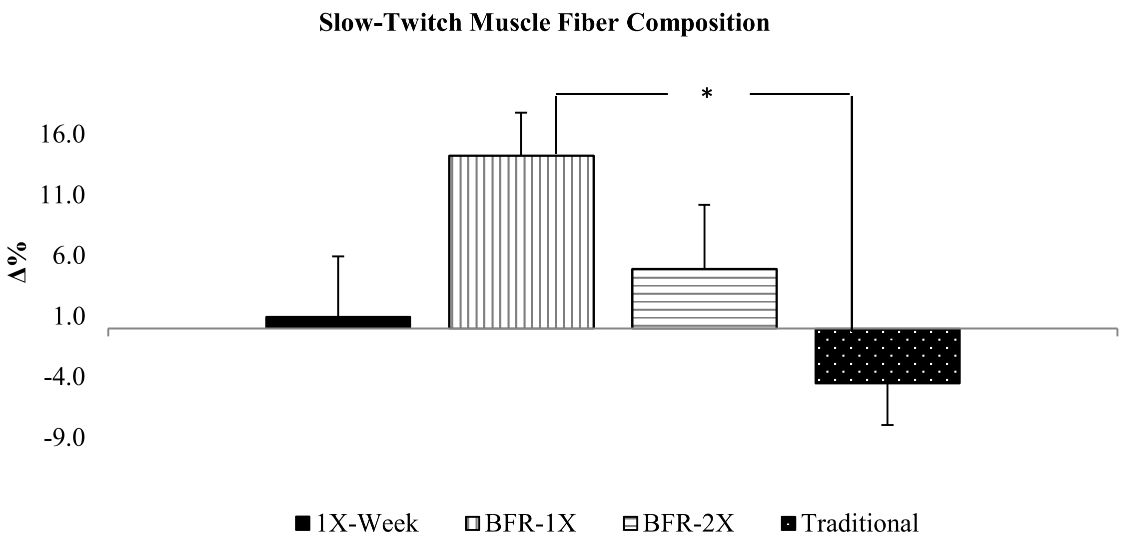
Figure 25 shows the effects the 4 different conditions had on ST muscle fiber composition after the 6-week training period and Figure 25A shows corresponding percent change in ST muscle fiber composition. No baseline differences between groups were detected and homogeneity of variances was confirmed by Levene's test of equality and variance. ANCOVA found a trend for condition main effect ($p = 0.08$). Follow-up pairwise comparison washed out the trend. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant interaction for time*condition ($p < 0.04$) and a significant condition ($p < 0.04$) main effect. For condition main effect, BFR-1X percent change in ST muscle fiber composition was significantly greater than BFR-1X.

Figure 25. Slow Twitch Muscle Fiber Composition



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Significant time*condition interaction (p<.04). Values reported as mean ±SE.

Figure 25A. Percent Change in Slow Twitch Muscle Fiber Composition

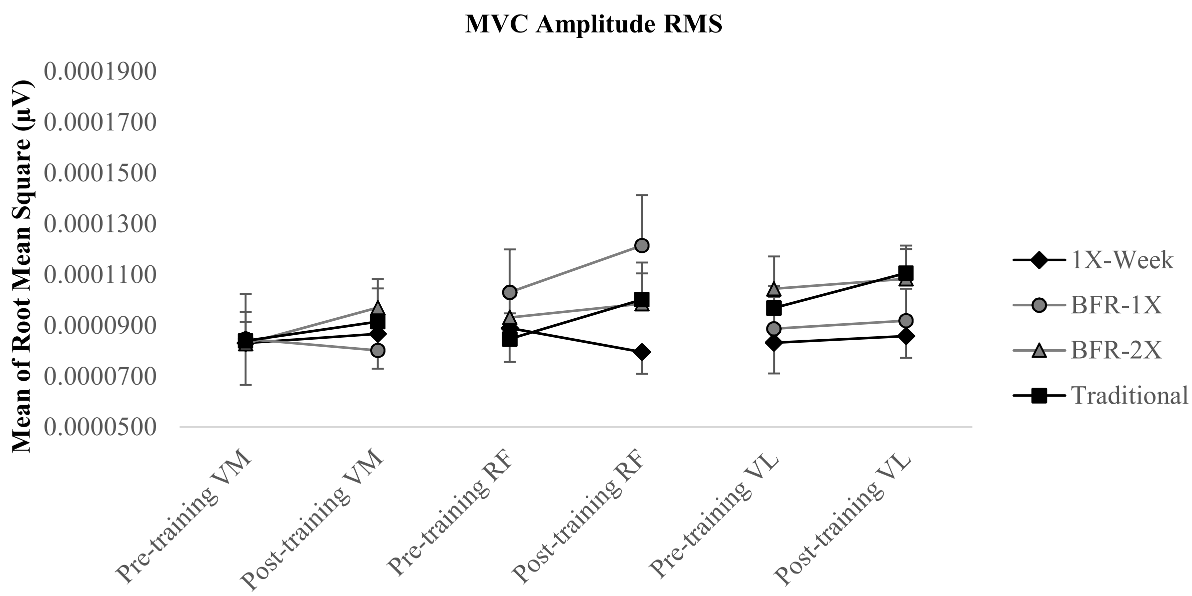


1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
* Significant condition difference (p<.04). Values reported as mean ±SE.

Neuromuscular Function

Figure 26 shows the effects the 4 different conditions had on EMG mean MVC amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. All other categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

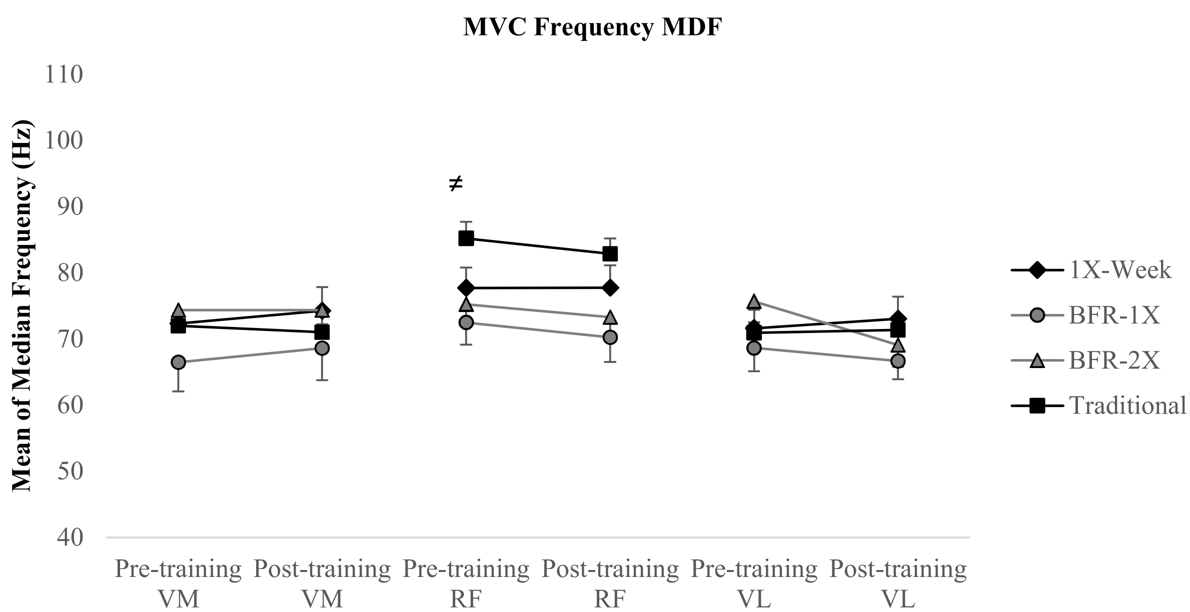
Figure 26. Amplitude during MVC test



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=11)
Values reported as mean ±SE.

Figure 27 shows the effects the 4 different conditions had on EMG mean MVC frequency after the 6-week training period. One-way ANOVA detected between-group differences ($p < 0.05$) at baseline RF. All other categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

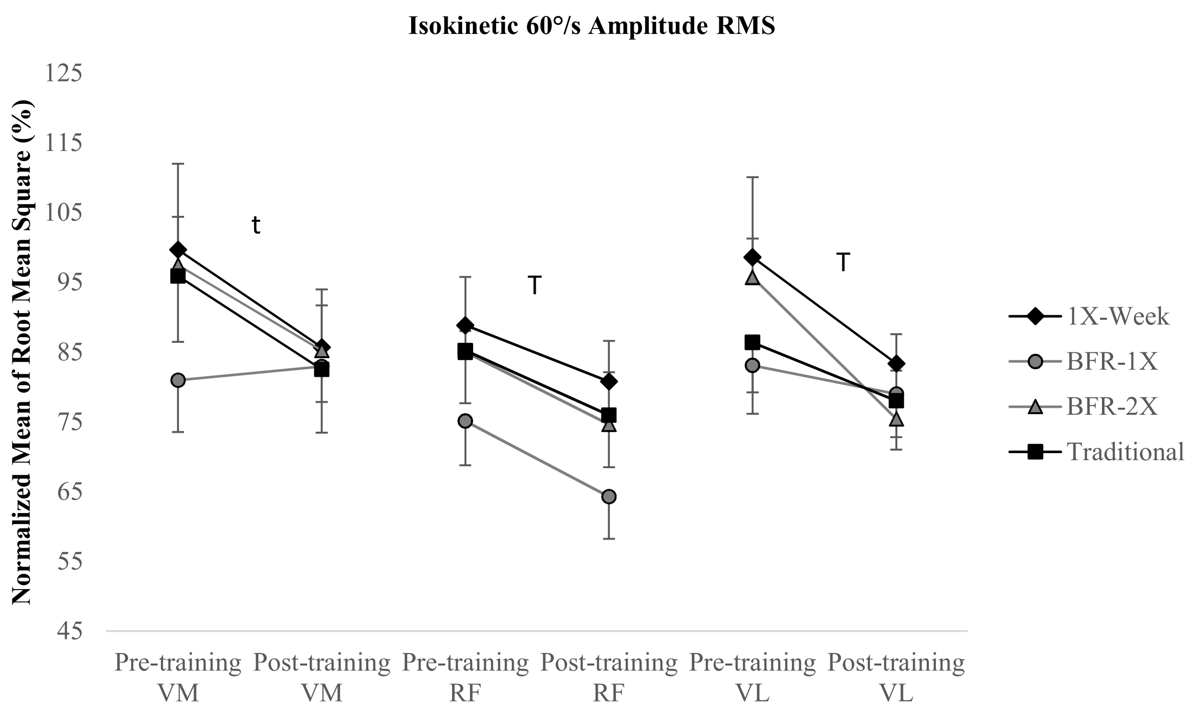
Figure 27. Frequency during MVC test



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
≠ Significant condition baseline difference (p<.05). Values reported as mean ±SE.

Figure 28 shows the effects the 4 different conditions had on EMG mean ISO-60°/s leg extensor amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a trend for VM time ($p < 0.07$) main effect and significant RF, VL time ($p < 0.01$) main effect. For significant and trend time main effects, post-training EMG mean ISO-60°/s leg extensor amplitude significantly less than pre-training in VM, RF and VL.

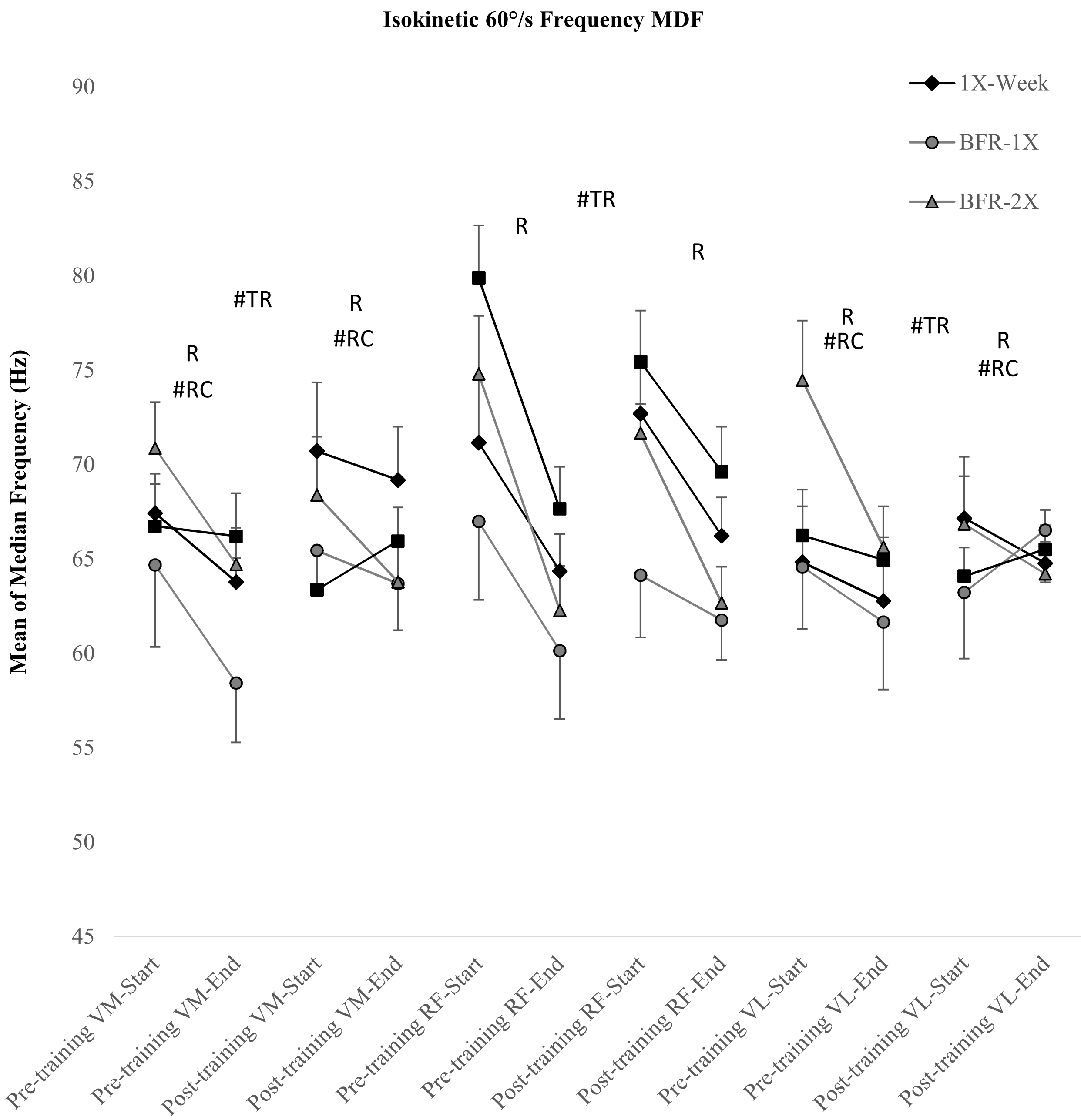
Figure 28. Amplitude during isokinetic leg extension (60°/s)



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.01). t Trend for time difference (p<.07). Values reported as mean ±SE.

Figure 29 shows the effects the 4 different conditions had on EMG mean ISO-60°/s leg extensor frequency after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant interaction for VM, VL reps*category ($p < 0.03$), significant interaction for VM, RF, VL time*reps ($p < 0.05$), and significant main effect VM, RF, VL reps ($p <0.01$). For significant reps main effect, end rep EMG mean ISO-60°/s leg extensor frequency was significantly less than starting rep for all times and conditions.

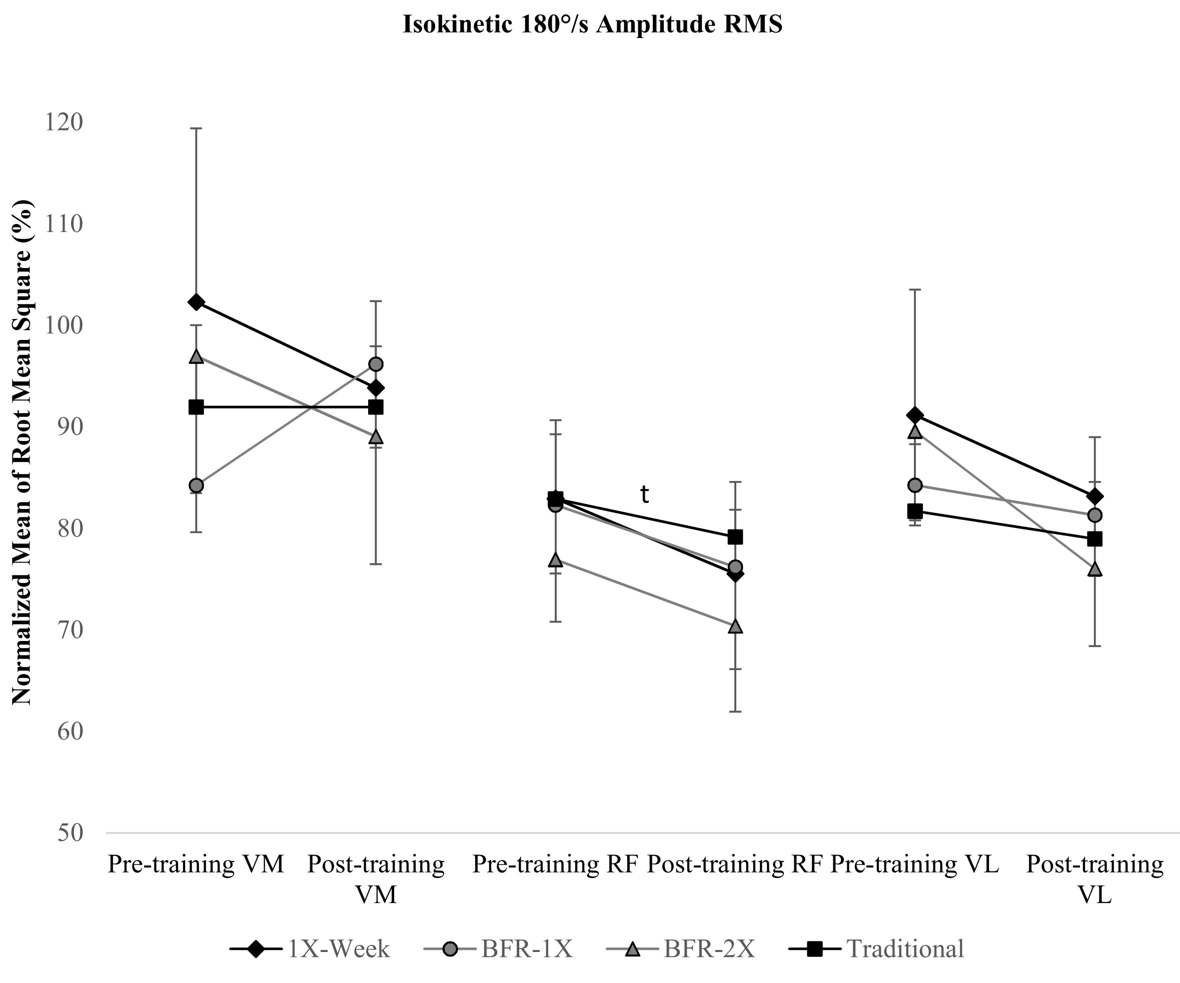
Figure 29. Frequency during isokinetic leg extension (60°/s)



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
R Significant rep difference ($p<.01$). #TR Significant time*reps interaction ($p<.05$). #RC Significant reps*condition interaction ($p<.05$). Values reported as mean ±SE.

Figure 30 shows the effects the 4 different conditions had on EMG mean ISO-180°/s leg extensor amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a trend for RF time main effect ($p < 0.09$). For trend in time main effect, post-training EMG mean ISO-180°/s leg extensor amplitude was less than pre-training.

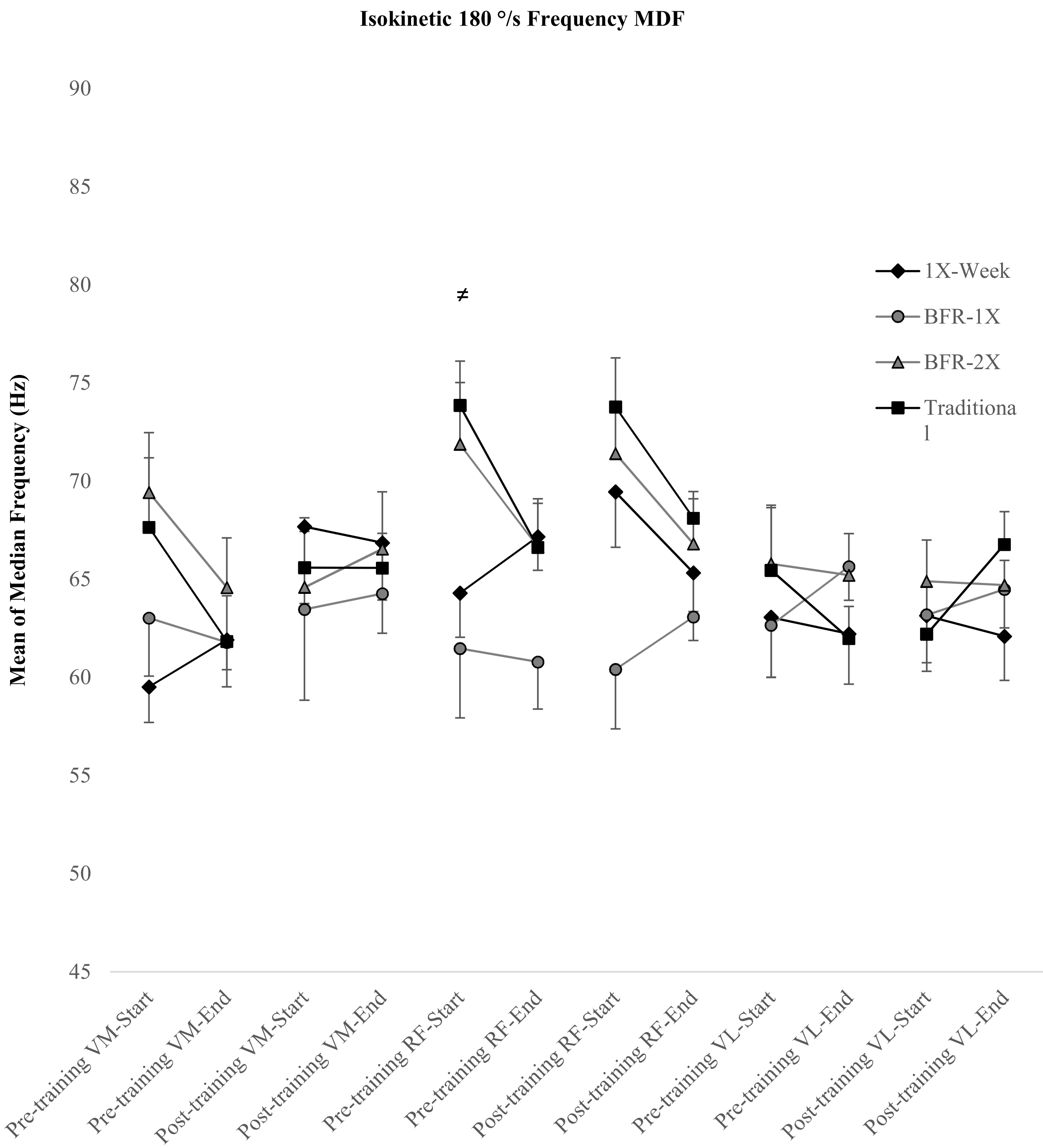
Figure 30. Amplitude during isokinetic leg extension (180°/s)



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
t Trend for time difference (p<.07). Values reported as mean ±SE.

Figure 31 shows the effects the 4 different conditions had on EMG mean ISO-180°/s leg extensor frequency after the 6-week training period. One-way ANOVA detected between-group differences of RF at baseline ($p < 0.05$). All other categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

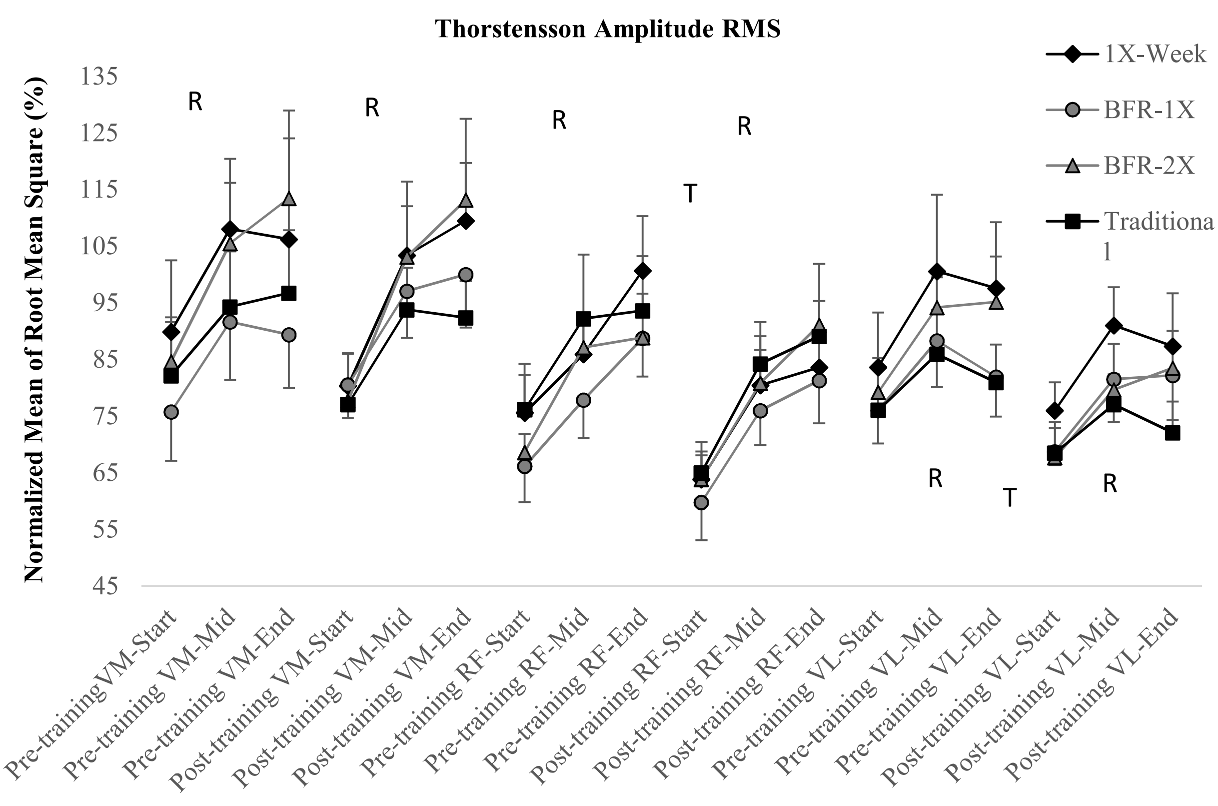
Figure 31. Frequency during isokinetic leg extension (180°/s)



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
≠ Significant condition RF baseline difference ($p<.05$). Values reported as mean ±SE.

Figure 32 shows the effects the 4 different conditions had on EMG mean Thorstensson ISO-180°/s leg extensor amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed significant VM, RF, VL reps ($p < 0.01$) main effect and significant RF, VL time ($p < 0.05$) main effect. For significant reps main effect, end rep EMG mean Thorstensson ISO-180°/s leg extensor amplitude was significantly greater than start rep for VM, RF, and VL at all times and conditions. For significant time main effect, post-training EMG mean Thorstensson ISO-180°/s leg extensor amplitude was significantly less than pre-training for RF and VL in all conditions.

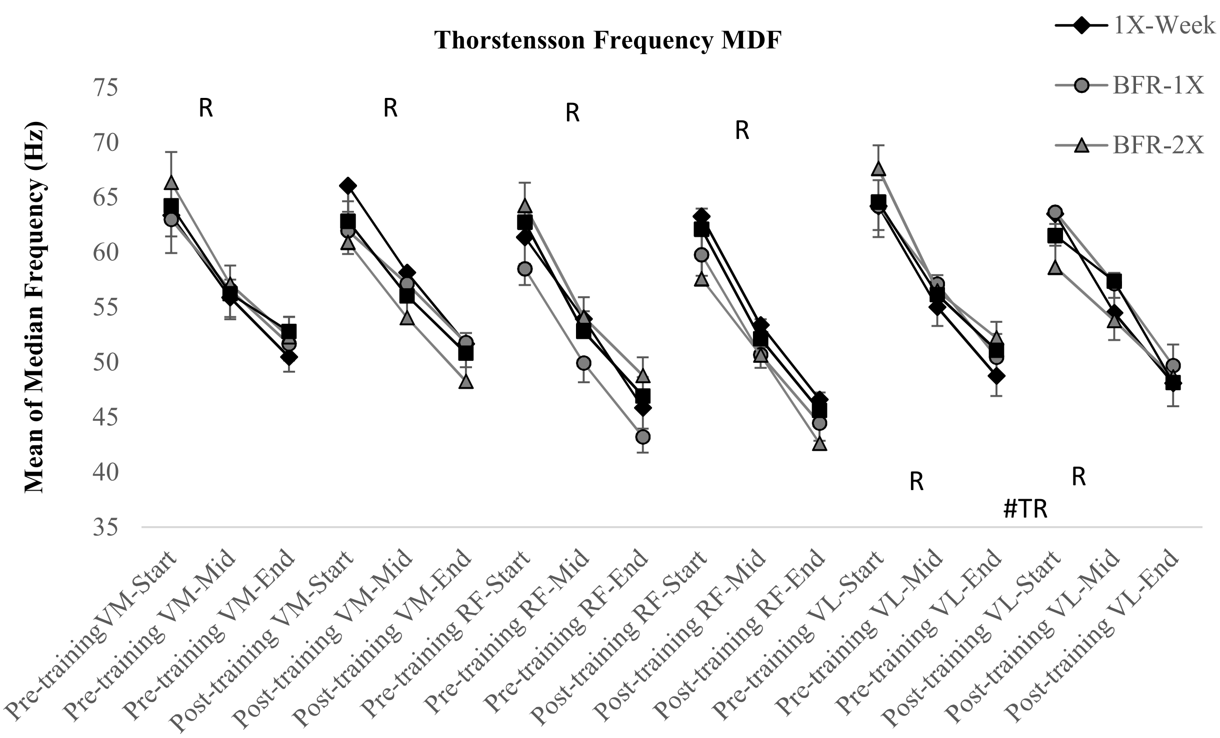
Figure 32. Amplitude during Thorstensson test



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
R Significant rep difference (p<.01). T Significant time difference (p<.05). Values reported as mean ±SE.

Figure 33 shows the effects the 4 different conditions had on EMG mean Thorstensson ISO-180°/s leg extensor frequency after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed significant VL time*reps ($p < 0.04$) interaction and significant VM, RF, VL reps ($p < 0.01$) main effect. For significant reps main effect, end rep EMG mean Thorstensson ISO-180°/s leg extensor frequency was significantly less than start rep for VM, RF, and VL at all times and conditions.

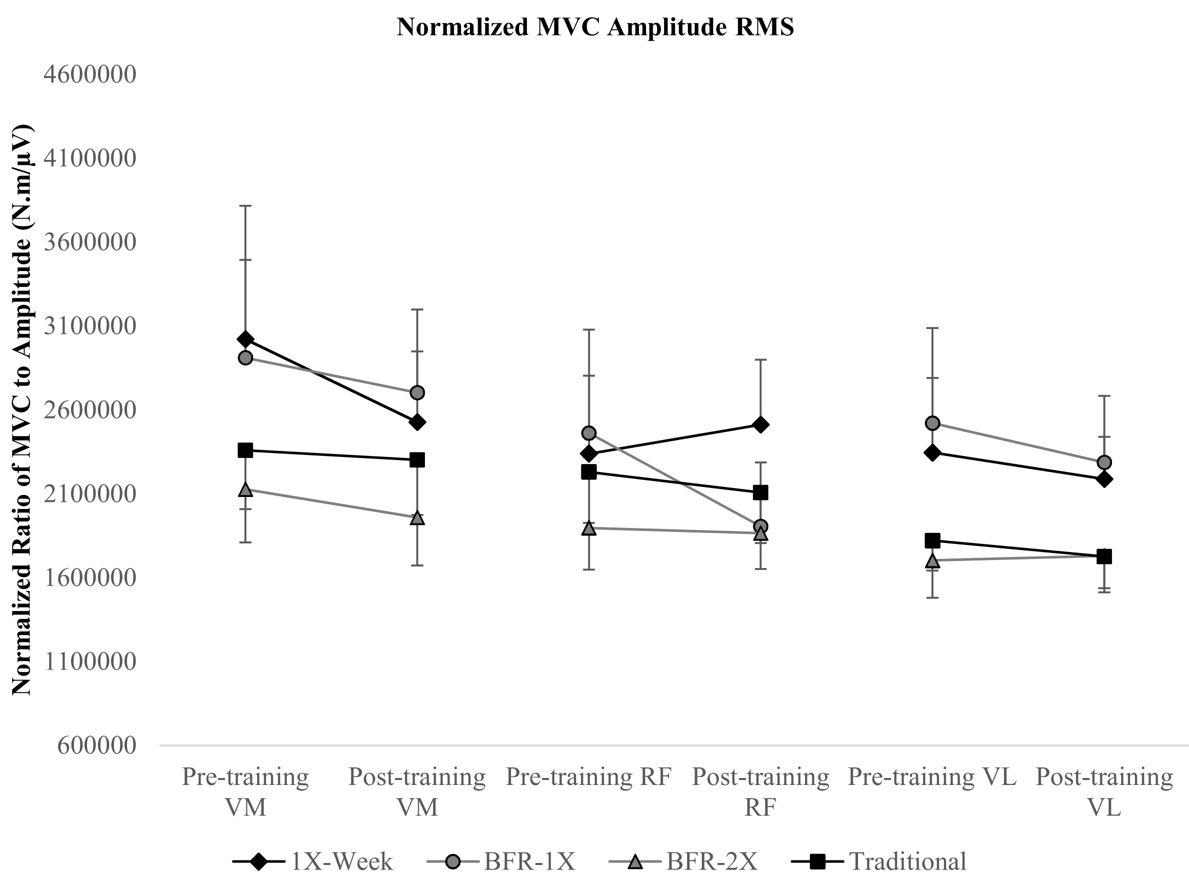
Figure 33. Frequency during Thorstensson test



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
R Significant rep difference (p<.01). #TR Significant time*reps interaction (p<.04). Values reported as mean ±SE

Figure 34 shows the effects the 4 different conditions had on EMG normalized MVC amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. All other categories were not statistically different ($p > 0.05$) for all condition and time main effects and interactions and they were reported together.

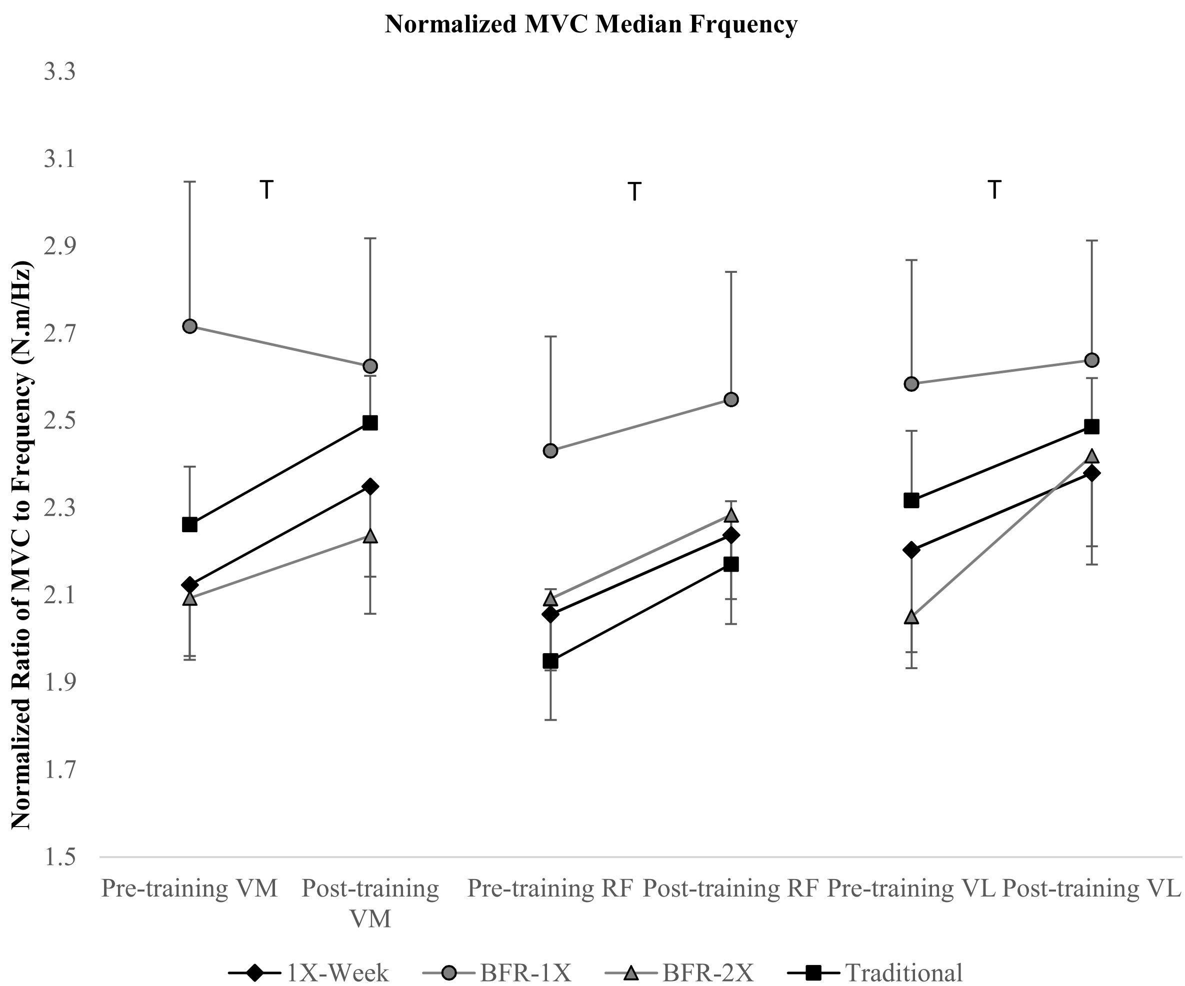
Figure 34. Normalized ratio of MVC to Amplitude



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
Values reported as mean ±SE

Figure 35 shows the effects the 4 different conditions had on EMG normalized MVC frequency after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed significant VM, RF, VL time main effects ($p < 0.04$). For significant time main effect, post-training EMG normalized MVC frequency was significantly greater for VM, RF, and VL in all conditions.

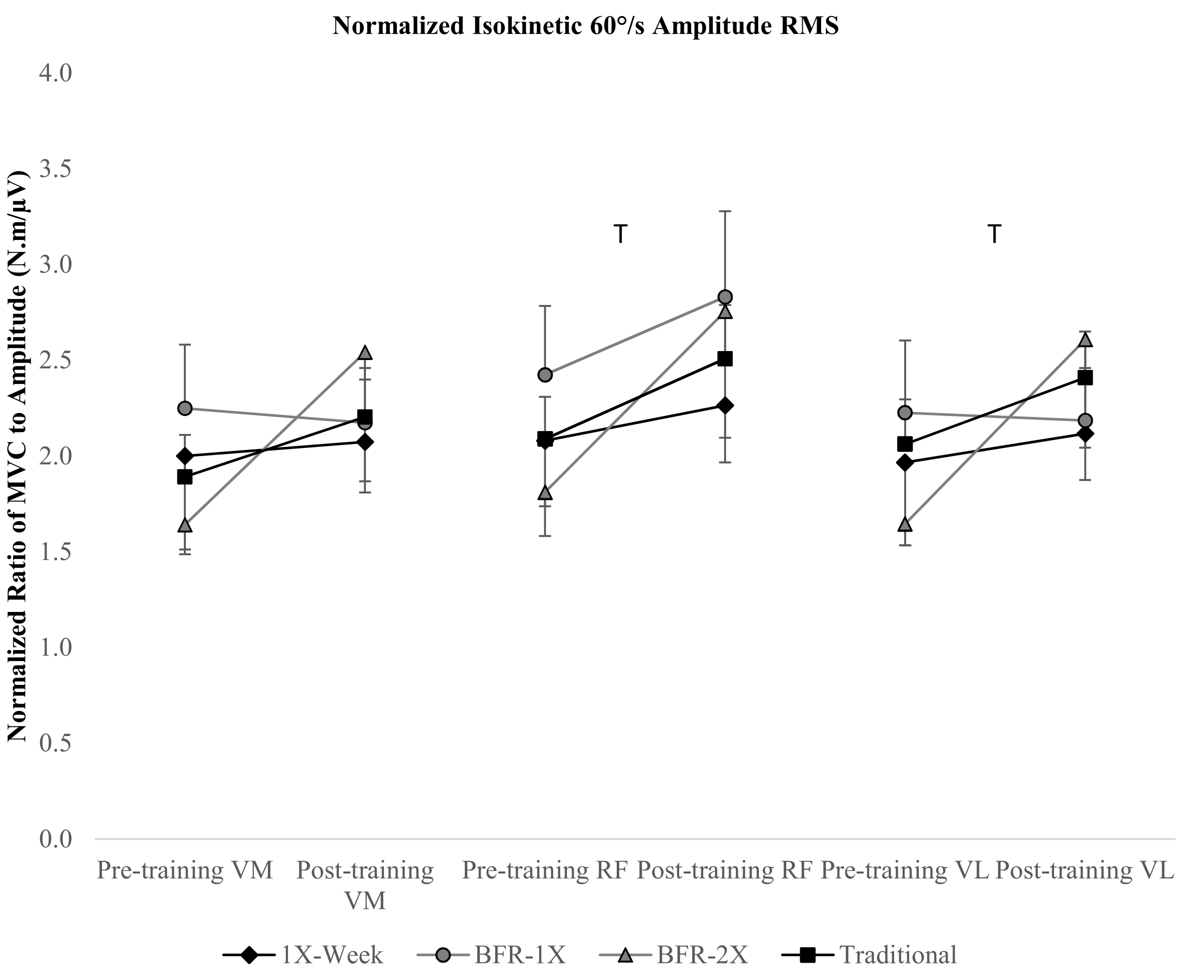
Figure 35. Normalized Ratio of MVC to Median Frequency



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.04). Values reported as mean ±SE

Figure 36 shows the effects the 4 different conditions had on EMG normalized ISO-60°/s leg extensor amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed significant RF, VL time main effects (p = 0.01). For significant time main effect, post-training EMG normalized ISO-60°/s leg extensor amplitude was significantly greater than pre-training for RF and VL in all conditions.

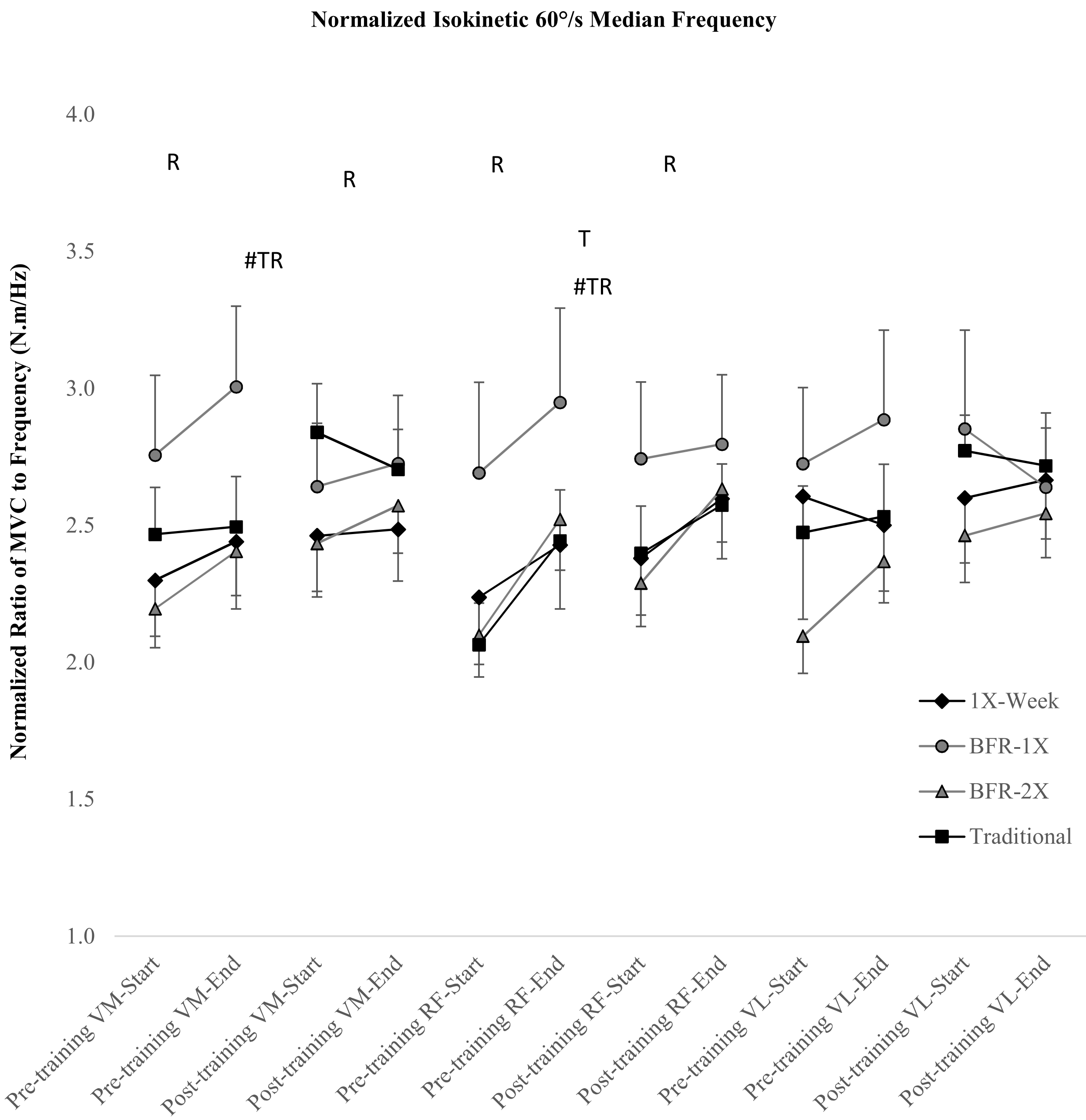
Figure 36. Normalized Ratio of Isokinetic 60°/s to Amplitude



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p=.01). Values reported as mean ±SE

Figure 37 shows the effects the 4 different conditions had on EMG normalized ISO-60°/s leg extensor frequency after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant interaction for VM, RF time*reps ($p < 0.05$), significant main effects for VM, RF reps ($p < 0.01$), and a significant RF time ($p < 0.04$) main effect. For significant rep main effects, end rep EMG normalized ISO-60°/s leg extensor frequency was significantly greater than start rep for VM and RF at all times and conditions. For significant time main effect, post-training EMG normalized ISO-60°/s leg extensor frequency was significantly greater than pre-training for RF in all times and conditions.

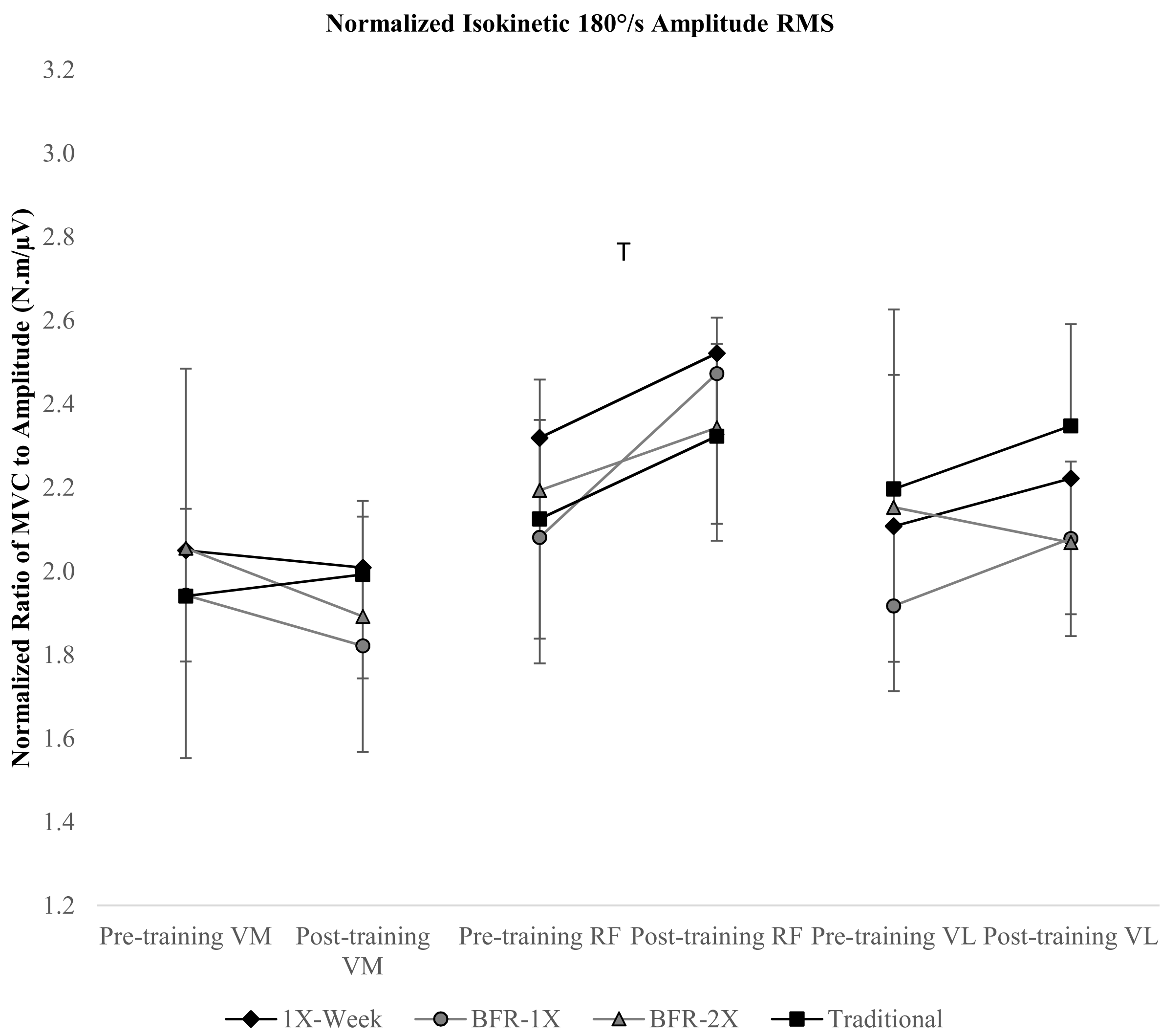
Figure 37. Normalized Ratio of Isokinetic 60°/s to Median Frequency



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.04). R Significant rep difference (p<.01). #TR Significant time*reps interaction (p<.05). Values reported as mean ±SE

Figure 38 shows the effects the 4 different conditions had on EMG normalized ISO-180°/s leg extensor amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant RF time main effect ($p < 0.05$). For significant time main effect, post-training EMG normalized ISO-180°/s leg extensor amplitude was greater than pre-training for RF in all conditions.

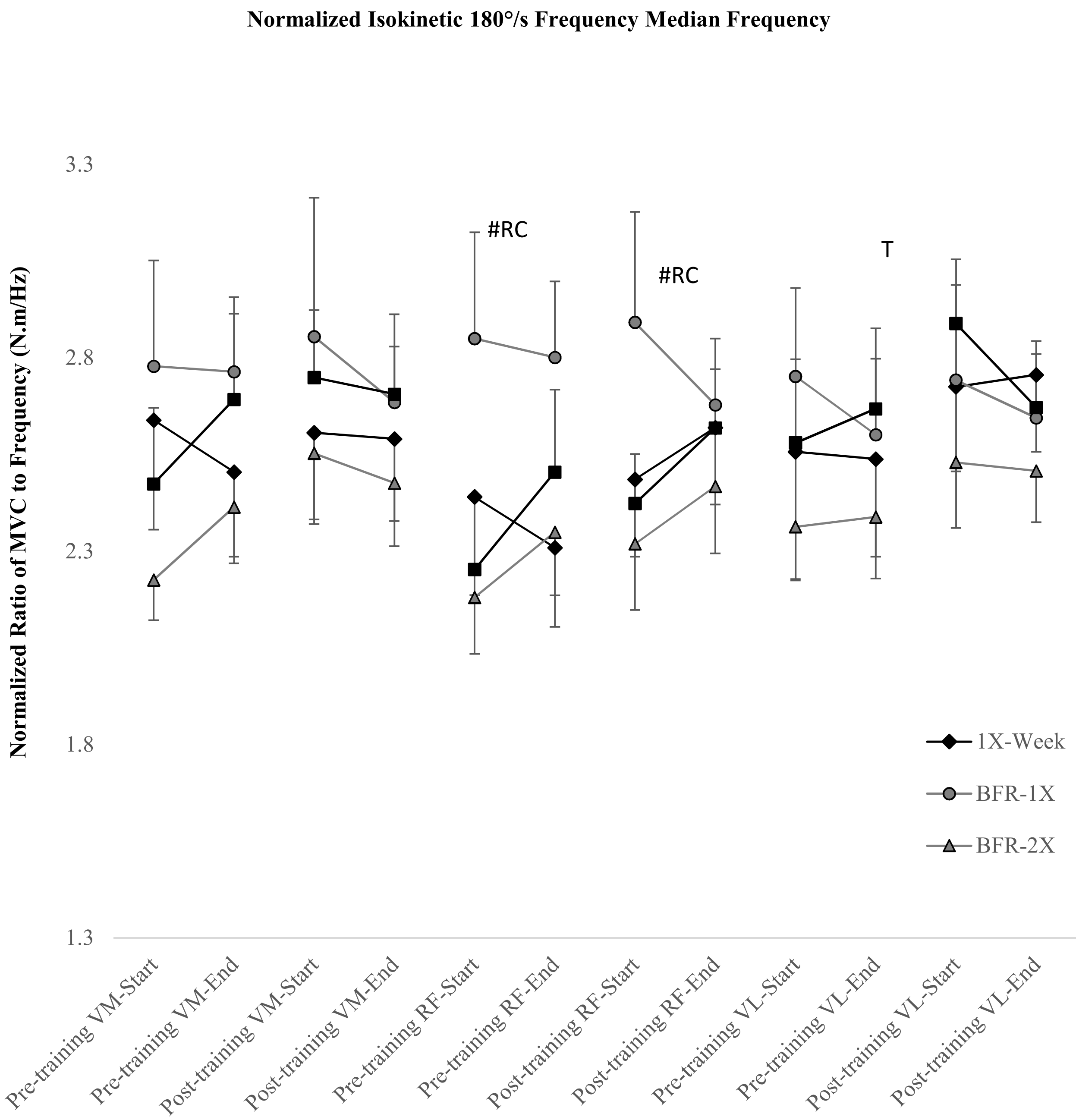
Figure 38. Normalized Ratio of Isokinetic 180°/s to Amplitude



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.05). Values reported as mean ±SE

Figure 39 shows the effects the 4 different conditions had on EMG normalized ISO-180°/s leg extensor frequency after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed a significant interaction ($p = 0.05$) for RF reps*condition and a significant time ($p < 0.05$) main effect for VL. For significant time main effect, post-training EMG normalized ISO-180°/s leg extensor frequency was significantly greater for than pre-training for VL in all conditions.

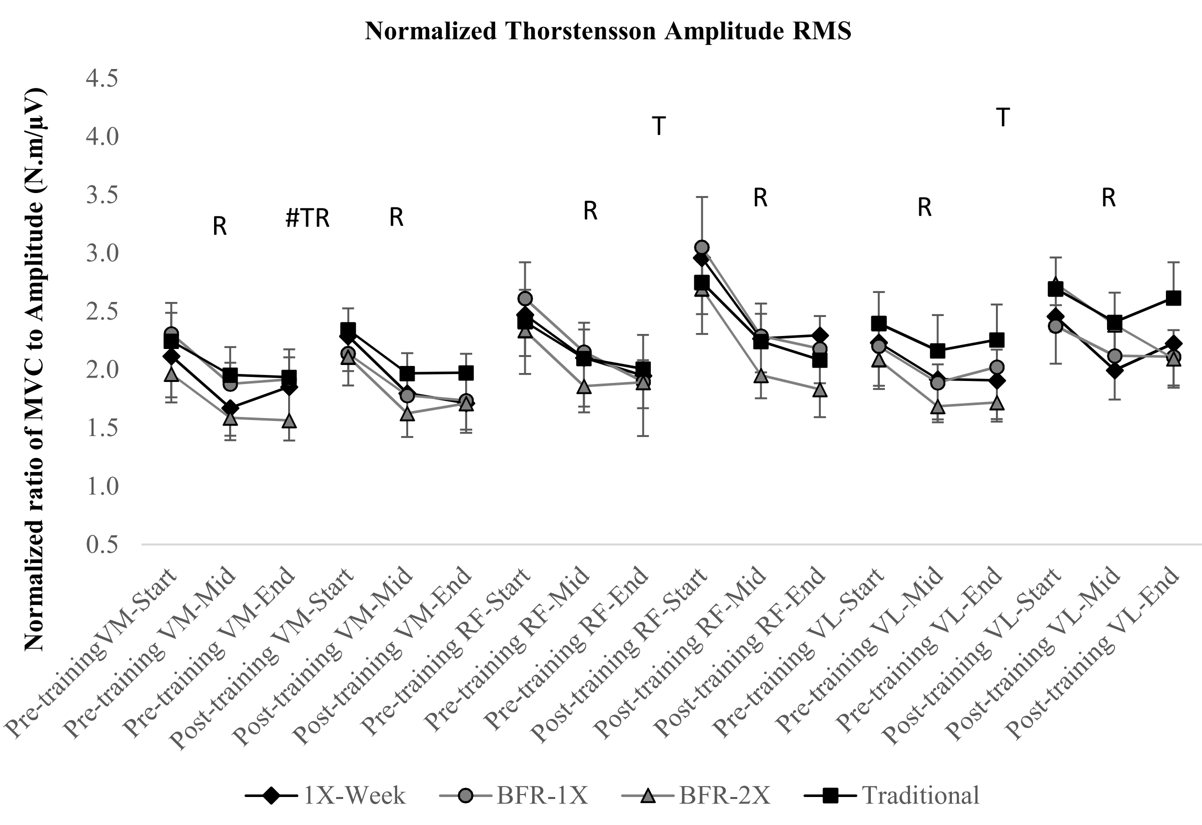
Figure 39. Normalized Isokinetic 180°/s Median Frequency



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.05). #RC Significant reps*condition interaction (p<.05). Values reported as mean ±SE

Figure 40 shows the effects the 4 different conditions had on EMG normalized Thorstensson ISO-180°/s leg extensor amplitude after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed significant VM time*reps interaction ($p < 0.03$) and significant VM, RF, VL reps ($p < 0.01$) and RF, VL time ($p < 0.01$) main effects. For significant reps main effect, end rep EMG normalized Thorstensson ISO-180°/s leg extensor amplitude was significantly less than start rep for VM, RF, and VL at all times and in all conditions. For significant time main effects, post training EMG normalized Thorstensson ISO-180°/s leg extensor amplitude was significantly greater than pre-training in RF and VL in all conditions.

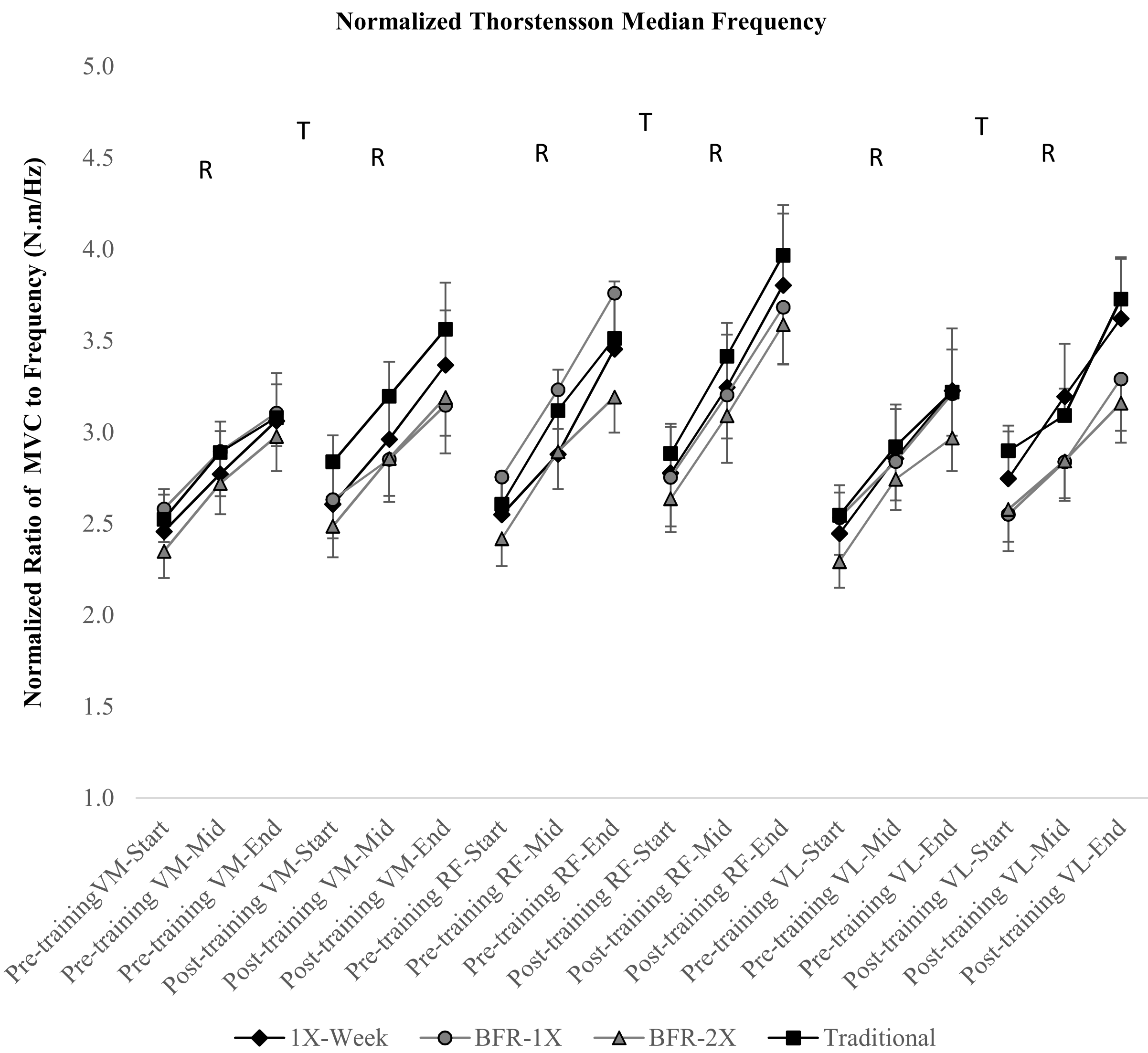
Figure 40. Normalized Ratio of Thorstensson to Amplitude



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.01). R Significant rep difference (p<.01). #TR Significant time*reps interaction (p<.03). Values reported as mean ±SE

Figure 41 shows the effects the 4 different conditions had on EMG normalized Thorstensson ISO-180°/s leg extensor frequency after the 6-week training period. One-way ANOVA did not detect between-group differences at baseline. Repeated measures ANOVA showed significant VM, RF, VL time ($p < 0.04$) and reps ($p < 0.01$) main effects. For significant time main effects, post-training EMG normalized Thorstensson ISO-180°/s leg extensor frequency was significantly higher than pre-training. For significant reps main effect, end rep EMG normalized Thorstensson ISO-180°/s leg extensor frequency was significantly greater than start rep for VM, RF, and VL at all times and in all conditions.

Figure 41. Normalized Ratio of Thorstensson to Median Frequency



1X-Week (N=12), BFR-1X (N=11), BFR-2X (N=11), Traditional (N=12)
T Significant time difference (p<.04). R Significant rep difference (p<.01). Values reported as mean ±SE

CHAPTER V

DISCUSSION

The purposes of this study were to 1) determine if subjects who were assigned to the blood flow restriction group had greater EMG activity, 2) determine whether or not subjects who were assigned to the lower frequency groups perform better in post-testing than those in the control (traditional) group, and 3) determine if blood flow restriction training resulted in better arterial elasticity and compliance than non-BFR resistance training.

Results

Strength Measures

All reported measures of strength had significant time main effects, yet in almost all cases conditions were not statistically different with the exception of the LE-1RM. These findings were in agreement with multiple studies that compared different frequencies and volumes (Burt et al., 2007; DiFrancisco-Donaghue et al., 2007; Gentil et al., 2015; Graves et al., 1990; Hass et al., 2000; Martín□Hernández et al., 2013; Serra et al., 2015; Taaffe et al., 1999). When comparing multiple frequencies of training, whether controlling for volume or not, significant increases in strength for all groups still occurred. However, like in the current study, there were no significant differences between groups as seen in multiple other studies (Burt et al., 2007; DiFrancisco-Donaghue et al., 2007; Gentil et al., 2015; Graves et al., 1990; Hass et al., 2000; Martín□Hernández et al., 2013; Serra et al., 2015; Taaffe et al., 1999).

LE-1RM ($p < 0.01$) significant condition main effects

One key and novel finding that the present study reported was that the lowest frequency group (1X-Week) significantly outperformed all other conditions in the LE-1RM and ISO-60°/s leg extensor torque. This significant finding by the current study was similar to only one other study, that is known of, which showed that a low-frequency, high-intensity resistance training protocol was superior to all other conditions at the LE-1RM (Martín-Hernández et al., 2013). This group, however, trained multiple sets twice per week as opposed to the single working set once per week imposed in the current study, and although it was a low frequency protocol (2 days/week), it was not lower in frequency or volume than the other conditions in the study (Martín-Hernández et al., 2013). A possible explanation for the difference between groups shown by Martín-Hernández et al. (2013) is that the significantly greater condition trained just as frequently and at a higher intensity than the other groups. Higher intensity training beginning at approximately 60% 1RM and upward has been shown to cause greater strength increases than lower intensity training, and the condition that was demonstrated to cause significantly greater increases in LE-1RM intensity began at 85% 1RM compared to the other groups at 29% 1RM (Campos et al., 2002; Rhea et al., 2003).

Contrasting evidence in the literature is quite common, as it should be since the current study is the only one known to have demonstrated a statistically significant superiority of a lower frequency and volume condition in muscular strength, specifically LE-1RM. The concept that greater volume and/or higher frequency conditions should outperform the lower ones in strength performance is not new, it is a very logical and well documented concept (Braith et al., 1989; Candow & Burke, 2007; DeMichele et al., 1997; Krieger, 2009; McKenzie, 1981; McLester et al., 2000; Schoenfeld et al., 2016). Possible main explanations offered for findings in these

contrasting studies are threefold: First, gender may play a role (the present study was comprised solely of young female subjects, whereas the majority of the literature represents males). Second, training status may explain magnitude and/or mechanism of strength increases; untrained will increase more than trained. Lastly, intensity nature of training conditions may affect adaptations (muscular failure versus traditional).

There are but two studies known to the authors that nearly parallel the present study design but fail to replicate the results. Burt et al. (2007) is one of the two studies known to the authors that is most highly comparable to the present, in which untrained females trained once or twice per week, performing a single working set on the leg press to muscular failure; however, these are the only two training groups in their study and they are not compared to a more traditional resistance training condition. Burt et al. (2007) reports that both conditions increase strength significantly, but there is no difference between groups, as opposed to the present study that demonstrates the once per week group as superior, with regards to strength measures. The other study (Sanborn et al., 2000) that compares with the present, and makes up for where Burt et al. (2007) falls short, was done by Sanborn et al. (2000) in which young untrained women train three times a week for eight weeks. They then compared a one set to failure group against a multiple set variation group not to failure (Sanborn et al., 2000). The only thing different about Sanborn et al. (2000) is the frequency, three days a week versus one in the present study, and their conclusion that the multiple set variation group not to failure was superior to a single set to failure. The current study remains the only one known to demonstrate the superiority of a condition with lesser volume and frequency than the other groups regarding muscular strength (LE-1RM).

A proposed explanation for the superior performance of 1X/week at the one-rep max leg extension and is the specificity of training. Also proposed by Martín-Hernández (2013), the six weeks of training with heavier loads (>70% 1RM) could have given the 1X/week group more practice with lifting heavy loads on the leg extension and thus a greater advantage when it came to the one-rep max test, but this same logic did not apply to the leg curl results. This practice of lifting and training with heavy loads, could have allowed for their skill at lifting heavy loads more near a 1RM max than the other groups could have given the 1X/week group an edge.

Thorstensson ISO-180°/s leg extensor torque

Significant time ($p < 0.01$) main effects were shown for all reps (Start, Mid, End) and all conditions for torque values produced during the Thorstensson test. Some interesting statistics to look at as well regarding the Thorstensson test is the muscle fiber type composition, which is what the muscular fatigue over the 50 repetitions in the test will demonstrate (Thorstensson et al., 1976). Specifically, the percent decline in torque from the initial to the ending repetitions will determine FT muscle fiber composition percentage, and by extension ST percentage as well (Thorstensson et al., 1976). Trends for condition ($p = 0.08$) main effects were shown for both FT muscle fiber type composition and ST muscle fiber type composition. BFR groups decreased in FT, but increased in ST while non-BFR groups increased in FT, but decreased in ST. Repeated measures showed a significant time*condition ($p < 0.04$) interaction for FT muscle fiber type composition occurring between BFR-1X and BFR-2X, showing that BFR-1X lost more FT than BFR-2X. There was an identical significant time*condition interaction for ST muscle fiber type composition. Significant condition ($p < 0.04$) main effects were also shown for percent change in FT and ST muscle fiber composition. Traditional FT muscle percentage composition increased

the most and was significantly greater than BFR-1X, while the opposite was true for ST percentage composition.

The compilation of trends and significance seen is in agreement with the current literature and what should be expected for the given intensity differences between the conditions. The higher intensity conditions (1X/Week and Traditional) gained more FT while the lower intensity conditions (BFR groups) gained more ST, which is the predicted outcome of such intensities of training in the literature (Rhea et al., 2003). BFR training however has been shown to differ in comparison to traditional resistance training, and it has been suggested that it may recruit more FT fibers due to hypoxia in the restricted muscles (Karabulut et al., 2010). The results of the present study however suggest that the BFR conditions imposed favored endurance, or ST, adaptations. The literature is lacking in this area, as this is the only study to present muscle fiber type shift changes, as shown by the Thorstensson test, and does not have much to compare to.

Hemodynamic Responses

There were no significant findings of any hemodynamic measure regarding time or condition differences in the present study. Systolic, diastolic, and mean arterial did not change significantly over time due to any condition. Previous studies have shown varying effects of resistance training on blood pressure. The literature has provided consistent evidence that has shown that resistance training with and without blood flow restriction, especially of lower intensities, has the capability to lower blood pressure (Collier et al., 2008; Ozaki et al., 2013). Conversely, multiple studies have shown an increase in blood pressure following resistance training, especially at higher intensities, (Cortez-Cooper et al., 2005; Miyachi et al., 2004; Okamoto et al., 2011) as well as for BFR training, but only acutely (Neto et al., 2016; Staunton et al., 2015; Takano et al., 2006). The findings of the current study have also been demonstrated

by previous studies (Figueroa & Vicil, 2011; Fahs et al, 2012) and may be largely explained by the normotensive baseline levels of a young female population. Baseline average of 112.7mmHg/65.6mmHg (SBP/DBP) for all subjects is a very good value to begin with, and thus any beneficial effects caused by training conditions had no significant effect, but should also be noted that the higher intensity conditions did not cause any significant increase either.

The remaining hemodynamic measures of pulse pressure, pulse rate, cardiac ejection time stroke volume, cardiac output, vascular resistance, and vascular impedance all remained unchanged after training in the present study. Any differences to have occurred in the aforementioned variables have been noted acutely following resistance and aerobic training (Brandner et al., 2015; Renzi et al., 2010). There is a lack of literature with regards to outcomes of these parameters following a resistance training regimen, with or without blood flow restriction. The fact that all these values remained stagnant could be due to the initial [healthy/normal] status of the population and/or the 6-week training was not long enough (did not accumulate enough volume) to spur change in these areas.

Arterial Compliance/Stiffness

For the purposes of the current study, arterial stiffness and compliance will refer to pulse wave velocity (PWV) and arterial elasticity index measures, respectively. All aspects of arterial compliance in the current study did not change significantly over time, in response to any condition, or interact with other factors. Typically, any increase in arterial compliance is associated with exercise of the aerobic nature and, in contrast, any decrease is associated with resistance exercise (DeVan et al., 2005; Fahs et al., 2009; Kingwell et al., 1997; Wilkinson et al., 2002). There are multiple studies that oppose these findings and show that resistance exercise, specifically lower intensity, with and without blood flow restriction can improve or cause no

change in arterial compliance and stiffness (Kim et al., 2009; Ozaki et al., 2011). Both Ozaki et al (2011) and Kim et al (2009) pitted a lower intensity BFR group against a higher intensity traditional group. Arterial compliance and stiffness remained unchanged in both BFR groups and increased for higher intensity group in Ozaki et al (2011), but not Kim et al (2009) possibly due to the shorter training period.

Pulse wave velocity, both peripheral and central, and arterial elasticity (small and large) experienced no significant changes following six week of resistance training with and without blood flow restriction. Although the aforementioned results demonstrated throughout the literature are not in uniform agreement, one would still expect at least the 1X-Week to failure condition, and likely the traditional condition, to have decreased arterial compliance and increased stiffness due to higher intensities of training. Baseline measures of LAE and SAE are 17.7 and 10.3 respectively, which is above normal for both measures. Similarly to a normotensive baseline having a greater likelihood to increase, this above average elasticity would have a greater inclination to decrease. Multiple studies showed that populations that typically benefitted from resistance exercise were those pre-hypertensives and higher in blood pressure, and those at normal levels (like in the present study) resulted in negative arterial compliance/stiffness outcomes (Collier et al., 2008). The absence of any change in elasticity and central or peripheral stiffness could be due to an insufficient increase in blood pressure during training, although this is unlikely due to the nature of the training conditions.

Neuromuscular Function

It has been shown in multiple studies that blood flow restriction resistance exercise, as performed in two of the conditions in the present study, can cause increases in electromyography (EMG) activity of the active muscle(s), for example the extensor muscles of the leg/quadriceps

involved in the leg extension (Moritani et al., 1992; Takarada et al., 2000; 2002). The literature is lacking information on the neuromuscular adaptations that occur following a period of training, more seriously with regards to BFR training. The present study filled this gap by reporting EMG activity in the leg extensor muscles prior to and following a six-week training program of four different training conditions, including two with BFR.

While the present study did demonstrate many significant differences in EMG activity throughout all the extensor muscles in the quadriceps across many different tests (MVC, Isokinetic 60°/s, Isokinetic 180°/s, and Thorstensson) it did not support the hypothesis that the BFR training condition(s) would prove to be significant as a main effect. The present study did not identify any condition as a significant main effect, it did show significant time and repetitions main effects as well as significant time*repetitions, time*condition, and repetitions*condition interactions.

The current study is the first of its kind known to report specific neuromuscular adaptations via EMG for specific muscles that occur in response to a training period in multiple conditions, especially with regards to BFR. As such, there is not much to compare against, but the overall results and changes in EMG activity are consistent with the well-established mechanism that neural adaptations will cause the initial strength increases and increases attributed to muscular hypertrophy will not occur for approximately six weeks following the onset of training (Sale, 1988). The EMG results demonstrated for BFR conditions should also be taken into consideration when considering the mechanism of muscle adaptation to BFR conditions. A considerable amount of the current literature is proposing a reverse in the pattern of adaptations, and contributing the initial increases to strength to hypertrophy in as little as two weeks (Loenneke et al., 2011). The present study does not agree with this proposed reverse in the

mechanism because EMG increases occurred concurrently with strength following 6 weeks of training, while body weight and composition remained unchanged. The significant time ($p<0.01$) main effect for increases in LE-1RM in all conditions occurred harmoniously with a significant time ($p < 0.04$) main effect for increases in EMG normalized MVC median frequency for all muscles (VM, VF, VL) in all conditions. That means that the increase in LE-1RM occurred in conjunction with all of the leg extensor muscles ability to produce force (N.m/Hz) as shown by EMG data during a nearly identical test and stimulus, but performed on dynamometer. However, it should be noted that studies to report this shift employed different means rather than EMG in order to attribute strength gains to neural adaptations and in most cases used MRI to report hypertrophy (Loenneke et al., 2011).

All significant main effects presented in the results were unable to isolate any condition difference. All significant time and rep main effects were exhibited in all conditions, leading us to the conclusion that the neural adaptations that occur in response to BFR resistance training and non-BFR resistance training are very similar, and thus the pattern of strength adaptation too would be comparable between the two modalities.

Conclusions

The purposes of this study were to 1) determine if subjects who were assigned to the blood flow restriction group had greater EMG activity, 2) determine whether or not subjects who were assigned to the lower frequency groups perform better in post-testing than those in the control (traditional) group, and 3) determine if blood flow restriction training resulted in better arterial elasticity and compliance than non-BFR resistance training.

The research questions asked were:

1) Did subjects who were assigned to the blood flow restriction group(s) have greater EMG activity than other conditions?

2) Did subjects who were assigned to the research group(s) perform as good as or better in post-testing than those in the traditional group?

3) Did blood flow restriction result in better arterial elasticity and compliance than other conditions?

Research Hypothesis 1. Blood flow restriction group(s) will have greater EMG activity than other conditions.

The results of the present study did not support this hypothesis. It was hypothesized that the greater EMG activity demonstrated during BFR resistance exercises would translate to increased EMG activity in the active muscles post-training without BFR cuffs on. Although this was the case, it also occurred in the other conditions.

Research Hypothesis 2. All conditions will demonstrate statistically significant increases in strength indices. Any differences between groups will not be statistically significant.

The results of the present study did not support this hypothesis. It was hypothesized that because of initial training condition and previous results seen in the literature that all conditions would increase strength measures, but that no condition would be statistically different from the others. However, the current study demonstrated the 1X/week condition was significantly greater than all other conditions in the one-rep max leg extension and significantly greater than BFR1X/week at 60°/s isokinetic extensor torque.

Research Hypothesis 3. There would be significant differences in arterial elasticity and compliance between BFR and non-BFR groups.

The results of the present study did not support this hypothesis. It was hypothesized that due to the lower intensity of BFR and findings of previous studies that BFR would have either no impact or a beneficial impact on arterial elasticity and compliance while non-BFR would have a negative impact, resulting in significant differences. However, the current study showed no significances of any kind for arterial elasticity and compliance.

This study is this first to have investigated the direct neural adaptations that occur following a 6-week resistance training program in concurrence with the coinciding muscular adaptations in multiple conditions (1X-Week, BFR-1X, BFR-2X, Traditional). The investigation supports the currently accepted mechanism for strength increases, that neural adaptations account for initial gains, for both traditional and BFR resistance training modalities. This study also showed that all the conditions imposed were effective, while 1X-Week was the best, at improving strength, but some muscular adaptations may vary between the modalities as evidenced by the shift in muscle fiber type; from FT to ST for BFR and vice versa for non-BFR. Lastly, this study demonstrated no significant changes whatsoever in any hemodynamic, arterial compliance, or arterial stiffness measure throughout all groups.

To conclude, any of the resistance training protocols throughout the groups will provide beginners with an effective template for increasing strength. The insignificance between groups is just as exciting and perhaps more applicable because it indicates that the individual can then choose a protocol that best suits them, but the 1X-Week condition may be superior (especially for LE-1RM). For those concerned with the association between resistance exercise and arterial compliance and stiffness, none of the conditions imposed had any effect (positive or negative),

so again the protocol that best suits the individual may be the best option. The results of this investigation could be very valuable in exercise prescription for beginners looking to start a resistance training program, as the time investment required to meet current recommendations is often a deterring factor, and the outcomes demonstrated offer more time-efficient protocols. Future investigations should investigate if there is a minimum intensity required to garner increases in strength and muscular adaptations, as well as continue to investigate a single-set to failure versus other conditions in beginners as the literature is still inconsistent.

REFERENCES

Aagaard, P., Simonsen, E. B., Andersen, J. L., Magnusson, P., & Dyhre-Poulsen, P. (2002). Increased rate of force development and neural drive of human skeletal muscle following resistance training. *Journal of applied physiology*, *93*(4), 1318-1326.

Abe, T., Fujita, S., Nakajima, T., Sakamaki, M., Ozaki, H., Ogasawara, R., & Sato, Y. (2010). Effects of low-intensity cycle training with restricted leg blood flow on thigh muscle volume and VO2max in young men. *J Sports Sci Med*, *9*(3), 452-8.

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

Abe, T., Sakamaki, M., Fujita, S., Ozaki, H., Sugaya, M., Sato, Y., & Nakajima, T. (2010). Effects of Low-Intensity Walk Training With Restricted Leg Blood Flow on Muscle Strength and Aerobic Capacity in Older Adults. *Journal of geriatric physical therapy*, *33*(1), 34-40.

Al Hazzouri, A. Z., Newman, A. B., Simonsick, E., Sink, K. M., Tyrrell, K. S., Watson, N., ... & Yaffe, K. (2013). Pulse wave velocity and cognitive decline in elders. *Stroke*, *44*(2), 388-393.

American College of Sports Medicine. (2013). *ACSM's Guidelines for Exercise Testing and Prescription*. 9th edition. Lippincott Williams & Wilkins, Philadelphia, PA.

Arnett, D. K., Evans, G. W., & Riley, W. A. (1994). Arterial stiffness: a new cardiovascular risk factor? *Am J Epidemiol, 140*(8), 669-682.

Braith, R. W., Graves, J. E., Pollock, M. L., Leggett, S. L., Carpenter, D. M., & Colvin, A. B. (1989). Comparison of 2 vs 3 days/week of variable resistance training during 10-and 18-week programs. *International journal of sports medicine*, *10*(06), 450-454.

Branca, F., Nikogosian, H., & Lobstein, T. (2007). *The challenge of obesity in the WHO European Region and the strategies for response*. Retrieved from http://www.euro.who.int/document/E90711.pdf

Brandner, C. R., Kidgell, D. J., & Warmington, S. A. (2015). Unilateral bicep curl hemodynamics: Low□pressure continuous vs high□pressure intermittent blood flow restriction. *Scandinavian journal of medicine & science in sports*, *25*(6), 770-777.

Burt, J., Wilson, R., & Willardson, J. M. (2007). A comparison of once versus twice per week training on leg press strength in women. *Journal of sports medicine and physical fitness*, *47*(1), 13.

Cameron, J. D., & Dart, A. M. (1994). Exercise training increases total systemic arterial compliance in humans. *Am J Physiol, 266*(2 Pt 2), H693-701.

Campos, G. E., Luecke, T. J., Wendeln, H. K., Toma, K., Hagerman, F. C., Murray, T. F., ... & Staron, R. S. (2002). Muscular adaptations in response to three different resistance-training regimens: specificity of repetition maximum training zones. *European journal of applied physiology*, *88*(1), 50-60.

Candow, D. G., & Burke, D. G. (2007). Effect of short-term equal-volume resistance training with different workout frequency on muscle mass and strength in untrained men and women. *The Journal of Strength & Conditioning Research*, *21*(1), 204-207.

Carpinelli, R. N., & Otto, R. M. (1998). Strength training: single versus multiple sets. *Sports medicine*, *26*(2), 73-84.

Clark, B. C., Manini, T. M., Hoffman, R. L., Williams, P. S., Guiler, M. K., Knutson, M. J., ... & Kushnick, M. R. (2011). Relative safety of 4 weeks of blood flow□restricted resistance exercise in young, healthy adults. *Scandinavian journal of medicine & science in sports*, *21*(5), 653-662.

Collier, S. R., Kanaley, J. A., Carhart, R., Frechette, V., Tobin, M. M., Hall, A. K., ... & Fernhall, B. (2008). Effect of 4 weeks of aerobic or resistance exercise training on arterial stiffness, blood flow and blood pressure in pre-and stage-1 hypertensives. *Journal of human hypertension*, *22*(10), 678-686.

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

DeMichele, P. L., Pollock, M. L., Graves, J. E., Foster, D. N., Carpenter, D., Garzarella, L., ... & Fulton, M. (1997). Isometric torso rotation strength: effect of training frequency on its development. *Archives of physical medicine and rehabilitation*, *78*(1), 64-69.

DeVan, A. E., Anton, M. M., Cook, J. N., Neidre, D. B., Cortez-Cooper, M. Y., & Tanaka, H. (2005). Acute effects of resistance exercise on arterial compliance. *Journal of Applied Physiology*, *98*(6), 2287-2291.

DiFrancisco-Donoghue, J., Werner, W., & Douris, P. C. (2007). Comparison of once-weekly and twice-weekly strength training in older adults. *British journal of sports medicine*, *41*(1), 19-22.

Edwards, D. G., Schofield, R. S., Magyari, P. M., Nichols, W. W., & Braith, R. W. (2004). Effect of exercise training on central aortic pressure wave reflection in coronary artery disease. *Am J Hypertens, 17*(6), 540-543. doi:10.1016/j.amjhyper.2003.12.001

Fahs, C. A., Rossow, L. M., Seo, D. I., Loenneke, J. P., Sherk, V. D., Kim, E., ... & Bemben, M. G. (2011). Effect of different types of resistance exercise on arterial compliance and calf blood flow. *European journal of applied physiology*, *111*(12), 2969-2975.

Fazlıoğlu, M., Şentürk, T., Kumbay, E., Kaderli, A. A., Yilmaz, Y., Özdemir, B., ... & Aydınlar, A. (2009). Small arterial elasticity predicts the extent of coronary artery disease: relationship with serum uric acid. *Atherosclerosis*, *202*(1), 200-204.

Figueroa, A., & Vicil, F. (2011). Post□exercise aortic hemodynamic responses to low□intensity resistance exercise with and without vascular occlusion. *Scandinavian journal of medicine & science in sports*, *21*(3), 431-436.

Garber, C. E., Blissmer, B., Deschenes, M. R., Franklin, B. A., Lamonte, M. J., Lee, I. M., ... & Swain, D. P. (2011). American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Medicine and science in sports and exercise*, *43*(7), 1334-1359.

Gentil, P., Fischer, B., Martorelli, A. S., Lima, R. M., & Bottaro, M. (2015). Effects of equal-volume resistance training performed one or two times a week in upper body muscle size and strength of untrained young men. *J Sports Med Phys Fitness*, *55*(3), 144-9.

Graves, J. E., Pollock, M. L., Foster, D., Leggett, S. H., Carpenter, D. M., Vuoso, R., & Jones, A. (1990). Effect of training frequency and specificity on isometric lumbar extension strength. *Spine*, *15*(6), 504-509.

Grey, E., Bratteli, C., Glasser, S. P., Alinder, C., Finkelstein, S. M., Lindgren, B. R., & Cohn, J. N. (2003). Reduced small artery but not large artery elasticity is an independent risk marker for cardiovascular events. *American journal of hypertension*, *16*(4), 265-269.

Häkkinen, K., Alen, M., & Komi, P. V. (1985). Changes in isometric force□and relaxation□ time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiologica*, *125*(4), 573-585.

Hass, C. J., Garzarella, L., De Hoyos, D., & Pollock, M. L. (2000). Single versus multiple sets in long-term recreational weightlifters. *Medicine and science in sports and exercise*, *32*(1), 235-242.

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

Karabulut, M., Cramer, J. T., Abe, T., Sato, Y., & Bemben, M. G. (2010). Neuromuscular fatigue following low-intensity dynamic exercise with externally applied vascular restriction. *Journal of Electromyography and Kinesiology*, *20*(3), 440-447.

Karabulut, M., & Perez, G. (2013). Neuromuscular response to varying pressures created by tightness of restriction cuff. *Journal of Electromyography and Kinesiology*, *23*(6), 1494-1498.

Kim, S. J., Sherk, V. D., Bemben, M. G., & Bemben, D. A. (2009). Effects of short-term, low-intensity resistance training with vascular restriction on arterial compliance in untrained young men. *International Journal of KAATSU Training Research*, *5*(1), 1-8.

Kingwell, B. A., Berry, K. L., Cameron, J. D., Jennings, G. L., & Dart, A. M. (1997). Arterial compliance increases after moderate-intensity cycling. *American Journal of Physiology-Heart and Circulatory Physiology*, *42*(5), H2186.

Krieger, J. W. (2009). Single versus multiple sets of resistance exercise: a meta-regression. *The Journal of Strength & Conditioning Research*, *23*(6), 1890-1901.

Krieger, J. W. (2010). Single vs. multiple sets of resistance exercise for muscle hypertrophy: a meta-analysis. *The Journal of Strength & Conditioning Research*, *24*(4), 1150-1159.

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

Loenneke, J., Abe, T., Wilson, J., Thiebaud, R., Fahs, C., Rossow, L., & Bemben, M. (2012). Blood flow restriction: an evidence based progressive model (Review). *Acta Physiologica Hungarica*, *99*(3), 235-250.

Loenneke, J., Fahs, C., Rossow, L., Abe, T., & Bemben, M. (2012). The anabolic benefits of venous blood flow restriction training may be induced by muscle cell swelling. *Medical Hypotheses, 78*(1), 151-154. doi:10.1016/j.mehy.2011.10.014

Loenneke, J. P., Thiebaud, R. S., & Abe, T. (2014). Does blood flow restriction result in skeletal muscle damage? A critical review of available evidence. *Scandinavian journal of medicine & science in sports*, *24*(6), e415-422.

Loenneke, J. P., Wilson, J. M., Wilson, G. J., Pujol, T. J., & Bemben, M. G. (2011). Potential safety issues with blood flow restriction training. *Scandinavian Journal of Medicine & Science in Sports, 21*(4), 510-518. doi:10.1111/j.1600-0838.2010.01290.x

Loenneke, J. P., Wilson, G. J., & Wilson, J. M. (2009). A Mechanistic Approach to Blood Flow Occlusion. *International Journal of Sports Medicine Int J Sports Med, 31*(01), 1-4.

Loenneke, J. P., Wilson, J. M., Marín, P. J., Zourdos, M. C., & Bemben, M. G. (2011). Low intensity blood flow restriction training: a meta-analysis. *European journal of applied physiology*, *112*(5), 1849-1859.

Martín-Hernández, J., Marín, P. J., Menéndez, H., Ferrero, C., Loenneke, J. P., & Herrero, A. J. (2013). Muscular adaptations after two different volumes of blood flow-restricted training. *Scandinavian journal of medicine & science in sports*, *23*(2), e114-e120.

Masuda, K., Masuda, T., Sadoyama, T., Inaki, M., & Katsuta, S. (1999). Changes in surface EMG parameters during static and dynamic fatiguing contractions. *Journal of Electromyography and Kinesiology*, *9*(1), 39-46.

McEniery, C. M. (2006). Novel therapeutic strategies for reducing arterial stiffness. *British journal of pharmacology*, *148*(7), 881-883.

Mceniery, C. M., Wallace, S., Mackenzie, I. S., Mcdonnell, B., Y., Newby, D. E. Wilkinson, I. B. (2006). Endothelial Function Is Associated With Pulse Pressure, Pulse Wave Velocity, and Augmentation Index in Healthy Humans. *Hypertension, 48*(4), 602-608.

McKenzie, G. G. (1981). Effects of frequency of weight training on muscle strength enhancement. *The Journal of sports medicine and physical fitness*, *21*(4), 432.

McLESTER, J. R., Bishop, E., & Guilliams, M. E. (2000). Comparison of 1 Day and 3 Days Per Week of Equal-Volume Resistance Training in Experienced Subjects. *The Journal of Strength & Conditioning Research*, *14*(3), 273-281.

Millasseau, S. C., Stewart, A. D., Patel, S. J., Redwood, S. R., & Chowienczyk, P. J. (2005). Evaluation of carotid-femoral pulse wave velocity: influence of timing algorithm and heart rate. *Hypertension, 45*(2), 222-226. doi:10.1161/01.HYP.0000154229.97341.d2

Moritani T, Michael-Sherman W, Shibata M, Matsumoto T, Shinohara M (1992) Oxygen availability and motor unit activity in humans. Eur J Appl Physiol 64:552-556.

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

Neto, G. R., Novaes, J. S., Dias, I., Brown, A., Vianna, J., & Cirilo-Sousa, M. S. (2016). Effects of resistance training with blood flow restriction on haemodynamics: a systematic review. *Clinical physiology and functional imaging*.

Okamoto, T., Masuhara, M., & Ikuta, K. (2011). Effect of low-intensity resistance training on arterial function. *European journal of applied physiology*, *111*(5), 743-748.

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

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

Park, S. Y., Kwak, Y. S., Harveson, A., Weavil, J. C., & Seo, K. E. (2015). Low intensity resistance exercise training with blood flow restriction: insight into cardiovascular function, and skeletal muscle hypertrophy in humans. *The Korean Journal of Physiology & Pharmacology*, *19*(3), 191-196.

Perri, M. G., Anton, S. D., Durning, P. E., Ketterson, T. U., Sydeman, S. J., Berlant, N. E., ... & Martin, A. D. (2002). Adherence to exercise prescriptions: effects of prescribing moderate versus higher levels of intensity and frequency. *Health Psychology*, *21*(5), 452.

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

Rhea, M. R., Alvar, B. A., Burkett, L. N., & Ball, S. D. (2003). A meta-analysis to determine the dose response for strength development. *Medicine and science in sports and exercise*, *35*(3), 456-464.

Robison, J., & Rogers, M. A. (1994). Adherence to exercise programmes. *Sports Medicine*, *17*(1), 39-52.

Russell, R. D., Nelson, A. G., & Kraemer, R. R. (2014). Short bouts of high-intensity resistance-style training produce similar reductions in fasting blood glucose of diabetic offspring and controls. *The Journal of Strength & Conditioning Research*, *28*(10), 2760-2767.

Sale, D. G. (1988). Neural adaptation to resistance training. *Medicine and science in sports and exercise*, *20*(5 Suppl), S135-45.

Sanborn, K., Boros, R., Hruby, J., Schilling, B., OBryant, H., Johnson, R., ... & STONE, M. (1998, November). Performance effects of weight training with multiple sets not to failure versus a single set to failure in women: A preliminary study. In *Presentation at the International Symposium on Weightlifting and Strength Training, Helsinki, Finland*.

Schjerve, I. E., Tyldum, G. A., Tjønna, A. E., Stølen, T., Loennechen, J. P., Hansen, H. E., ... & Smith, G. L. (2008). Both aerobic endurance and strength training programmes improve cardiovascular health in obese adults. *Clinical science*, *115*(9), 283-293.

Schoenfeld, B. J., Ogborn, D., & Krieger, J. W. (2016). Effects of resistance training frequency on measures of muscle hypertrophy: a systematic review and meta-analysis. *Sports Medicine*, *46*(11), 1689-1697.

Scott, B. R., Loenneke, J. P., Slattery, K. M., & Dascombe, B. J. (2015). Exercise with blood flow restriction: an updated evidence-based approach for enhanced muscular development. *Sports medicine*, *45*(3), 313-325.

Serra, R., Saavedra, F., de Salles, B. F., Dias, M. R., Costa, P. B., Alves, H., & Simão, R. (2015). The effects of resistance training frequency on strength gains. *Journal of Exercise Physiology Online*, *18*(1), 37-45.

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

Staron, R. S., Leonardi, M. J., Karapondo, D. L., Malicky, E. S., Falkel, J. E., Hagerman, F. C., & Hikida, R. S. (1991). Strength and skeletal muscle adaptations in heavy-resistance-trained women after detraining and retraining. *Journal of Applied Physiology*, *70*(2), 631-640.

Staunton, C. A., May, A. K., Brandner, C. R., & Warmington, S. A. (2015). Haemodynamics of aerobic and resistance blood flow restriction exercise in young and older adults. *European journal of applied physiology*, *115*(11), 2293-2302.

Stone, M. H., Plisk, S. S., Stone, M. E., Schilling, B. K., O'bryant, H. S., & Pierce, K. C. (1998). Athletic Performance Development: Volume Load---1 Set vs. Multiple Sets, Training Velocity and Training Variation. *Strength & Conditioning Journal*, *20*(6), 22-31.

Sugawara, J., Hayashi, K., Yokoi, T., Cortez-Cooper, M. Y., DeVan, A. E., Anton, M. A., & Tanaka, H. (2005). Brachial–ankle pulse wave velocity: an index of central arterial stiffness?. *Journal of human hypertension*, *19*(5), 401-406.

Suzuki, H. I. R. O. M. A. S. A., Conwit, R. A., Stashuk, D., Santarsiero, L., & Metter, E. J. (2002). Relationships between surface-detected EMG signals and motor unit activation. *Medicine and science in sports and exercise*, *34*(9), 1509-1517.

Taaffe, D. R., Duret, C., Wheeler, S., & Marcus, R. (1999). Once-weekly resistance exercise improves muscle strength and neuromuscular performance in older adults. *Journal of the American Geriatrics Society*, *47*(10), 1208-1214.

Takano, H., Morita, T., Iida, H., Asada, K. I., Kato, M., Uno, K., ... & Eto, F. (2005). Hemodynamic and hormonal responses to a short-term low-intensity resistance exercise with the reduction of muscle blood flow. *European journal of applied physiology*, *95*(1), 65-73.

Takarada Y, Sato Y, Ishii N (2002) Effects of resistance exercise combined with vascular occlusion on muscle function in athletes. Eur J Appl Physiol 86:308-314.

Takarada Y, Takazawa H, Sato Y, Takebayashi S, Tanaka Y, Ishii N (2000) Effects of resistance exercise combined with moderate vascular occlusion on muscular function in humans. J Appl Physiol 88:2097- 2106.

Tao, J., Jin, Y. F., Yang, Z., Wang, L. C., Gao, X. R., Lei, L., & Ma, H. (2004). Reduced arterial elasticity is associated with endothelial dysfunction in persons of advancing age Comparative study of noninvasive pulse wave analysis and laser doppler blood flow measurement. *American journal of hypertension*, *17*(8), 654-659.

Tsao, C. W., Lyass, A., Larson, M. G., Levy, D., Hamburg, N. M., Vita, J. A., ... & Vasan, R. S. (2015). Relation of central arterial stiffness to incident heart failure in the community. *Journal of the American Heart Association*, *4*(11), e002189.

Thorstensson, A., Grimby, G. U. N. N. A. R., & Karlsson, J. (1976). Force-velocity relations and fiber composition in human knee extensor muscles. *Journal of applied physiology*, *40*(1), 12-16.

World Health Organization. (2009). Global strategy on diet, physical activity and health: Obesity and overweight, 2004.

Wilkinson, I. B., Qasem, A., McEniery, C. M., Webb, D. J., Avolio, A. P., & Cockcroft, J. R. (2002). Nitric oxide regulates local arterial distensibility in vivo. *Circulation*, *105*(2), 213-217.

Yasuda, T., Fujita, T., Miyagi, Y., Kubota, Y., Sato, Y., Nakajima, T., ... & Abe, T. (2006). Electromyographic responses of arm and chest muscle during bench press exercise with and without KAATSU. *International Journal of KAATSU Training Research*, *2*(1), 15-18.

Yasuda, T., Loenneke, J. P., Thiebaud, R. S., & Abe, T. (2012). Effects of blood flow restricted low-intensity concentric or eccentric training on muscle size and strength. *Plos one*, *7*(12), e52843.

APPENDIX A

DEFINITIONS

1) PAR-Q: PAR-Q (Physical activity readiness questionnaire) is a screening tool that is designed to determine whether a subject may perform the exercise in a safe and risk-free manner.
2) Blood Flow Restriction (BFR): BFR is a technique that restricts venous blood return during exercise. This process involves cuffs placed over the inguinal crease, which are inflated to a specific pressure. The cuffs are 5 centimeters wide and contain an inflatable bladder.
3) Arterial compliance: the measurement of the elastic properties of the arteries, which has an inverse relationship with arterial stiffness.
4) Hemodynamics: Analysis of physical aspects of blood circulation and blood flow.
5) Pulse Wave Velocity: Noninvasive assessment of arterial compliance in which velocity of blood pressure wave forms traveling between two different sites are measured.
6) Hydration: Hydration status was deemed adequate when urine specific gravity measured 1.010 and lower as determined by a clinical urine refractometer.

LIST OF ABBREVIATIONS

ANOVA -Analysis of Variance
BFR -Blood Flow Restriction
CET -Cardiac Ejection Time
CO -Cardiac Output
DBP -Diastolic Blood Pressure
HR -Heart Rate
LAE -Large Arterial Elasticity
MAP -Mean Arterial Pressure
PAR-Q -Physical Activity Readiness Questionnaire
PP -Pulse Pressure
PR -Pulse Rate
PWV -Pulse Wave Velocity
SAE -Small Arterial Elasticity
SBP -Systolic Blood Pressure
SV -Stroke Volume
SVI -Stroke Volume Index
SVR -Systemic Vascular Resistance
TVI -Total Vascular Impedance
USG -Urine Specific Gravity

APPENDIX–FORMS

APPENDIX FORMS

1. RECRUITMENT FLYER

UTRGV

PARTICIPANTS NEEDED

You are invited to participate in an IRB approved research training study at the Health and Human Performance Department at the University of Texas Rio Grande Valley at Brownsville. The purpose of the study is to assess the neuromuscular and arterial compliance responses to different resistance training frequencies and protocols in untrained males and females. Total time required for completion of the study is 10-22 visits for a total of about 6-10 hours.

Please Contact for additional details:

Patrick Murphy	Brittany Esparza	Danny Dominguez
Tel: (512) 605-7937	Tel: (956) 545-7378	Tel: (956) 545-3174
patrick.murphy01@utrgv.edu	brittany.esparza01@utrgv.edu	danny.dominguez01@utrgv.edu

2. INFORMED CONSENT

Informed Consent Form to Participate in Research

Project Title: Neuromuscular and Arterial Compliance Responses to Different Resistance Training Frequencies and Protocols

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

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

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

Purpose
The purposes of this study are to 1) investigate the short-term training effects of the use of blood flow restriction cuffs during resistance training when compared to recommended protocols without blood flow restriction on large and small arterial elasticity, and 2) to examine how different programming with and without blood flow restriction will cause changes in hemodynamics by measuring resting heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, cardiac output, stroke volume, systemic vascular resistance, total vascular impedance, as well as strength indices by measuring maximum voluntary contraction, torque, power, force, electromyography, and one-repetition maximum in untrained individuals.

Number of Participants
80 sedentary to recreationally active, untrained male and/or female participants will take part of this study.

Procedures
If you agree to be in this study, you will be asked to do the following:
a. You will be required to visit the research labs in the Department of Health and Human Performance 10-22 separate days for a total time commitment of about 6-10 hours (depending upon which research group you are placed in).
b. On the first visit (about 90 minutes), you will fill out the health status questionnaire and be familiarized with the study procedures. You will also read and sign an informed consent and PAR-Q before any testing takes place (these forms will also be emailed to participants). Participants that answer yes to any PAR-Q question, or have blood pressure at or higher than 140/90 mmHg will be excluded from this study. If the participants qualify they will perform their one-rep max test.

All study procedures will be conducted in the Exercise Science Laboratory (M-1 building, room 216). Time schedules will be agreed on by the subject and researcher to when it is most convenient to the subject to be both fasted (for at least 8 hours) and hydrated, for pre and post testing. Hydration will be monitored with the use of a urine refractometer, that will require a subject to provide a urine sample to determine the level of current hydration (hydration is at or below 1.010). This study will be a total of 8 weeks long with weeks 1 and 8 consisting of pre and post testing and weeks 2- 7 consisting of actual training.

The University of Texas Rio Grande Valley
IRB APPROVED
IRB# 2016-173-09 (968133)
Expires: 10/16/2017

IRB APPROVED UTRGV

Informed Consent Form to Participate in Research

On the first day, the participants will fill out questionnaires and will be familiarized with the study procedures before starting the exercise sessions. Participants that answer yes to any PAR-Q question, or have blood pressure at or higher than 140/90 mmHg will be excluded from this study. Following initial screening (PAR-Q and health questionnaire, a copy of both forms will be provided) and familiarization, anthropometric measurements will include, resting heart rate, blood pressure, height, weight, body composition, and thigh circumference. Weight and body fat percentage will be measured using the BodPod (gold standard body composition based on air displacement). Thigh circumference will be taken at the mid-point of the greater trochanter and lateral epicondyle. Inflation of the blood flow restriction cuffs (elastic cuffs that are tightened and filled with air to restrict blood flow) will be based on thigh circumference: <45–50 cm = 120 mmHg; 51–55 cm = 150 mmHg; 56–59 cm = 180 mmHg; and ≥60 cm = 210 mmHg. Participants will also perform a one-rep max (1RM) test to determine future training weight. The second day will consist of collecting measurements using SphygmoCor, HDI, BodPod, and Biodex with EMG, this session will last for a total of 2 hours. When performing measurements using SphygmoCor the subjects will lie down in the supine position for a minimum of 10 minutes and baseline arterial elasticity and hemodynamics will be measured using Hypertension diagnostic (noninvasive equipment conducts measurements of arterial stiffness via placing a sensor on the radial artery at the right wrist and a cuff to the left arm to measure blood pressure) and measurement of pulse wave velocity using SphygmoCor (which is conducted noninvasively using a pulse wave velocity analyzer in segmental measures at the carotid, femoral, and the dorsalis pedis while wearing three electrodes on the chest to monitor the heart's electrical activity).

Any sessions prior to the beginning of week 2 will be introductory in nature, including initial paperwork and recording necessary values prior to training. Weeks 2-7 will include the actual training sessions in which each participant will come in and perform the specified routine in the exercise science lab using the resistance training machines 1 to 3 times a week, depending on which research group they are placed in, with at least one day of rest between sessions. Upon finishing the 6-week training program, week 8 will consist of measuring all variables that were recorded in week 1. For pre and post recordings subjects will be required to be fasted and hydrated prior to testing.

Once body anthropometric and body composition measurements have been taken, the subject will determine their one-rep max following testing protocol during their first week and last week. Heart rate (via Polar chest strap and watch) will be monitored continuously during any exercise portion. This first session will take about 35 minutes.

This study will consist of 4 different groups:

A control group that will train 3 days a week following ACSM resistance training recommendations and guidelines.

The high frequency blood flow restriction training group will train at 20-50% of their one-rep max 2 times a week.

The low frequency to failure blood flow restriction training group will train 20-50% of their one-rep max once a week.

The low frequency to failure non-BFR training group will train at 10-20 RM of their one-rep max once a week.

All training sessions will be performed in the exercise lab using 2 different machines; the leg curl and leg extension.

All training sessions will include a 5-minute warm-up on a cycle ergometer at 1.5 kp and 50 rpm.

Each training session in weeks 2-7 will take approximately 20 minutes.

The time training will be a total of 2, 4, or 6 hours for the 6 weeks of training depending on which research group a subject is placed in.

Week 8 will consist of measuring all variables that were recorded in week 1 as outlined above and will take the same amount of time.

Informed Consent Form to Participate in Research

Minimal Risk: The minimal risk includes discomfort using blood flow restriction cuff and performing the one-rep max test (the subject may feel tired right after the test and feel sore a day after the test). They will be screened in detail before being allowed to participate. If at any time they are unable to complete any task they will be allowed to stop.
The research team is required to calibrate all the equipment (which will be performed regularly according to instructions provided by the manufacture) know how to properly use the equipment, and have all documentation done to conduct research. The research team will conduct measurements on the subject of the same gender.

Length of Participation
You will be required to visit the research labs in the Department of Health and Human Performance on 10-22 separate days for a total time commitment of approximately 6-10 hours (depending on which research group you are placed in).

Risks
The study has the following risks:
You understand there are minimal risks to healthy individuals when performing any of the requirements for this project. However, even though these standard protocols have been approved at numerous other institutions and will be performed by qualified and trained personnel. You should be aware of the following: The minimal risks include discomfort using BFR cuff and performing one-rep max testing.

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

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

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

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

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

The University of Texas Rio Grande Valley
IRB APPROVED
IRB# 2016-173-09 (968133)
Expires: 10/16/2017

IRB APPROVED UTRGV

Informed Consent Form to Participate in Research

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

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

_____ I consent to being quoted directly.

_____ I do not consent to being quoted directly.

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

Contacts and Questions
If you have concerns, complaints, or questions about the research and/or the researcher(s) conducting this study you are encouraged to contact the Department of Health and Human Performance to speak to the principal investigator Dr. Murat Karabulut, Ph. D., at (956) 882-7236 or e-mail Murat.Karabulut@utrgv.edu. You may also contact any of the Co-Investigators: Patrick Murphy at Patrick.Murphy01@utrgv.edu, Brittany Esparza at Brittany.Esparza01@utrgv.edu, or Danny Dominguez at danny.dominguez01@utrgv.edu.

Who to Contact Regarding Your Rights as a Participant
This research has been reviewed and approved by the Institutional Review Board for Human Subjects Protection (IRB). If you have any questions about your rights as a participant, or if you feel that your rights as a participant were not adequately met by the researcher, please contact the IRB at (956) 665-2889 or irb@utrgv.edu.

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

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

Signature Date

The University of Texas Rio Grande Valley
IRB APPROVED
IRB# 2016-173-09 (968133)
Expires: 10/16/2017

IRB APPROVED UTRGV

3. PAR-Q

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

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

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

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

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

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

If you answered

YES to one or more questions

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

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

NO to all questions

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

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

DELAY BECOMING MUCH MORE ACTIVE:

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

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

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

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

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

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

NAME ____

SIGNATURE ____ DATE ______________________________

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

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

4. HEALTH STATUS QUESTIONNAIRE

HEALTH STATUS QUESTIONNAIRE

SECTION ONE - GENERAL INFORMATION

1. Date____________________
2. Name____
3. Mailing Address_____________________________________ Phone (H)______________

   _____________________________________ Phone (W)______________

   Email _____________________________________
4. *EI* Personal Physician_________________________________ Phone__________________

   Physician Address____________________________________ Fax____________________

   ____
5. *EI* Person to contact in case of emergency___________________ Phone__________________
6. Gender (circle one): Female ◯ Male *RF* ◯
7. *RF* Date of birth___________/_________/_____________
8. Height _____________________ Weight ________________________
9. Number of hours worked per week: Less than 20 ◯ 20-40 ◯ 41-60 over 60 ◯
10. *SLA* More than 25% of the time at your job is spent (circle all that apply)

    ◯ Sitting at desk ◯ Lifting loads ◯ Standing ◯ Walking ◯ Driving

SECTION TWO - CURRENT MEDICAL INFORMATION

11. Date of last medical physical exam:_____________
12. Circle all medicine taken of prescribed in last 6 months:

    ☐ Blood thinner *MC*
    ☐ Diabetic *MC*
    ☐ Digitalis *MC*
    ☐ Diuretic *MC*
    ☐ Epilepsy medication *SEP*
    ☐ Heart rhythm medication *MC*
    ☐ High blood pressure medication *MC*
    ☐ Insulin *MC*
    ☐ Nitroglycerin *MC*
    Other__________________
13. Please list any orthopedic conditions. Include any injuries in the last six months

    ____

14. Any of these health symptoms that occur frequently (two or more times/month) requires medical attention. Please check any that apply.

a. ☐ Cough up blood *MC*	g. ☐ Swollen joints *MC*
b. ☐ Abdominal pain *MC*	h. ☐ Feel faint *MC*
c. ☐ Low-back pain *MC*	i. ☐ Dizziness *MC*
d. ☐ Leg Pain *MC*	j. ☐ Breathlessness with slight exertion *MC*
e. ☐ Arm or shoulder pain *MC*	k. ☐ Palpitation or fast heart beat *MC*
f. ☐ Chest pain *RF MC*	l. ☐ Unusual fatigue with normal activity *MC*

Other____

SECTION THREE - MEDICAL HISTORY

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

☐ Alcoholism *SEP*	☐ Diabetes *SEP*	☐ Kidney problem *MC*
☐ Anemia, sickle cell *SEP*	☐ Emphysema *SEP*	☐ Mental illness *SEP*
☐ Anemia, other *SEP*	☐ Epilepsy *SEP*	☐ Neck strain *SLA*
☐ Asthma *SEP*	☐ Eye problems *SLA*	☐ Obesity *RF*
☐ Back strain *SLA*	☐ Gout *SLA*	☐ Phlebitis *MC*
☐ Bleeding trait *SEP*	☐ Hearing loss *SLA*	☐ Rheumatoid arthritis *SLA*
☐ Bronchitis, chronic *SEP*	☐ Heart problems *MC*	☐ Stress *RF*
☐ Stroke *MC*	☐ Cancer *SEP*	☐ High blood pressure *MC*
☐ Thyroid problem *SEP*	☐ Cirrhosis *MC*	☐ HIV *SEP*
☐ Ulcer *SEP*	☐ Concussion *MC*	☐ Hypoglycemia *SEP*
☐ Congenital defect *SEP*	☐ Hyperlipidemia *RF*	Other_____________________

16. Circle any operations that you have had:

☐ Back *SLA* ☐ Heart *MC* ☐ Kidney *SLA* ☐ Eyes *SLA* ☐ Joint *SLA* ☐ Neck *SLA*

☐ Ears *SLA* ☐ Hernia *SLA* ☐ Lung *SLA* Other_______________________________

17. *RF* Circle any who died of heart attack before age 55:

☐ Father ☐ Brother ☐ Son

18. *RF* Circle any who died of heart attack before age 65:

☐ Mother ☐ Sister ☐ Daughter

SECTION FOUR - HEALTH-RELATED BEHAVIORS

19. Have you ever smoked? Yes ◯ No ◯

20. *RF* Do you now smoke? Yes ◯ No ◯

21 .*RF* If you are a smoker, indicate the 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

22. *RF* Do you exercise regularly? Yes ◯ No ◯

23.. Last physical fitness test:__________________

24. How many days a week do you accumulate 30 minutes of moderate activity?

0 1 2 3 4 5 6 7 days per week

25. How many days per week do you normally spend at least 20 minutes in vigorous exercise?

0 1 2 3 4 5 6 7 days per week

26. What activities do you engage in a least 1x per week?

____

27. Weight now:__________lb. One year ago:__________ Age 21:__________

SECTION FIVE - HEALTH-RELATED ATTITUDES

28. These are traits that have been associated with coronary-prone behavior. Circle the number that corresponds to how you feel towards the following statement:

I am an impatient , time-conscious, hard-driving individual.

Circle the number that best describes how you feel:

◯ 6= Strongly agree ◯ 3= Slightly disagree
◯ 5= Moderately agree ◯ 2= Moderately disagree
◯ 4= Slightly agree ◯ 1= Strongly disagree

29. How often do you experience "negative" stress from each of the following:

	Always	Usually	Frequently	Rarely	Never
Work:	☐	☐	☐	☐	☐
Home or family :	☐	☐	☐	☐	☐
Financial pressure:	☐	☐	☐	☐	☐
Social pressure:	☐	☐	☐	☐	☐
Personal health	☐	☐	☐	☐	☐

30. List everything not included on this questionnaire that may cause you problems in a fitness test or fitness program:

____

____

____

____

Action Codes

EI = Emergency Information- must be readily available
MC= Medical Clearance needed-do not allow exercise without physician's permission.
SEP= Special Emergency Procedures needed- do not let participant exercise alone; make sure the person's exercise partner knows what to do in case of an emergency
RF= Risk Factor of CHD (educational materials and workshops needed).
SLA= Special or Limited Activities may be needed- you may need to include or exclude specific exercises.
Other (not marked) = Personal information that may be helpful for files or research.

5. DATA COLLECTION SHEET

HDI/*PulseWave*™ CR-2000
Research CardioVascular Profile Report

Research Subject ID:

Research Subject Name:

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

Average Blood Pressure Waveform

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

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

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

6. DATA COLLECTION SHEET 2

Pre Test

Name:____ Date:_______________

Height:__________________

Weight:_________________

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

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

BFR Leg Circumference:__________________ BFR Pressure:_______________

Split Squat 1 RM:___________________ Leg Extension 1 RM:__________________

Leg Curl 1 RM:_____________________

Date:___________________

USG:____________________

BodPod	
Weight	
Body Fat%	
Lean Weight	
Fat Weight	

Carotid:__________________

Radial:___________________

Femoral:_________________

Distal:___________________

C-R	
C-F	
F-D	

7. DATA COLLECTION SHEET 3

Subject ______________________

Time & Date ______________________

Group 1x/wk

Training Session ______________________

Exercise

	HR	RPE
Cycle	______	______

Leg Extension

Set	Reps	Complete	HR	RPE	Weight	
1	6				50% workload	KAA:
1 minutes rest						BA:
2	Max/ failure				75% 1RM	LLA:

2 MINUTES B/W EXERCISES

Leg Curl

Set	Reps	Complete	HR	RPE	Weight	
1	6				50% workload	Pad:
1 minutes rest						Adj:
2	Max/failure				75% 1RM	

8. DATA COLLECTION SHEET 4

Subject ______________________

Time & Date ______________________

Group **BFR 1x or 2x /wk**

Training Session ______________________

Exercise

	HR	RPE
Cycle	________	________

CUFF PRESSURE = [ ]

Leg Extension

Set	**Reps**	**Complete**	**HR**	**RPE**	**Rest (min**	**Weight**
1	30				1	KAA:
2	15				1	BA:
3	15				1	LLA:
4	15				1	

2 MINUTES REST B/W EXERCISES

Leg Curl

Set	**Reps**	**Complete**	**HR**	**RPE**	**Rest (mi**	**Weight**
1	30				1	Pad:
2	15				1	Adj:
3	15				1	
4	15				1	

9. DATA COLLECTION SHEET 5

Subject ______________________

Time & Date ______________________

Group **Control**

Training Session ______________________

Exercise

	HR	RPE
Cycle	________	________

Leg Extension

Set	**Reps**	**Complete**	**HR**	**RPE**	**Rest (min)**	**Weight**	
warm-up	6--10				**1**	50%(workload)	
1	10				2	50% 1RM	KAA:
2	10				2		BA:
3	10				2		LLA:

1 minute rest between exercises

Leg Curl

Set	**Reps**	**Complete**	**HR**	**RPE**	**Rest (min)**	**Weight**	
warm-up	6--10				**1**	50%(workload)	
1	10				2	50% 1RM	Pad:
2	10				2		Adj:
3	10				2		

10. PROFESSOR PERMISSION SCRIPT

The University of Texas Rio Grande Valley
Professor Permission Script

My name is Patrick Murphy/Danny Dominguez/Brittany Esparza; I am a graduate student and a staff member from the Department of Health and Human Performance at the University of Texas Rio Grande Valley (UTRGV). I would like to ask permission to enter your classroom to invite your students to participate in my research study. My study is about neuromuscular and arterial compliance responses to different resistance training frequencies and protocols in untrained males and females.

As part of participation, students will be asked to perform 10-22 sessions, which will include: A pre and post session in which the student will be asked to come in hydrated (which will be tested via urine sample) and fasted for one of them. These sessions will include body composition testing, anthropometric measuring, hemodynamics, one-rep max testing, and testing on the Biodex with electromyography sensors placed on student's legs. Students will come to the lab 1 to 3 times a week for approximately 20 minutes for each training sessions with or without blood flow restriction cuffs, depending on their assignment for a total of 6 weeks. The total time commitment is 6-10 hours, again depending on the group. Participation in this research is completely voluntary; they may choose not to participate without penalty. All data will be confidential by being collected by Patrick Murphy, Brittany Esparza, Danny Dominguez, and Murat Karabulut, and later stored in a locked file cabinet for 3 years.

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

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

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

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

Do I have your permission to recruit students from your classroom(s) Dr. Murat Karabulut?
Do I have your permission to recruit students from your classroom(s) Dr. Ulka Karabulut?
Do I have your permission to recruit students from your classroom(s) Dr. Merill Funk?
Do I have your permission to recruit students from your classroom(s) Ms. Margarita Gonzalez?

11. IN-PERSON RECRUITMENT SCRIPT

The University of Texas Rio Grande Valley
Recruitment Script

My name is Gage Murphy/Brittany Esparza/Danny Dominguez; I am a graduate student and a staff member from the Department of Health and Human Performance at the University of Texas Rio Grande Valley (UTRGV). I would like to invite you to participate in my research study: Neuromuscular and arterial compliance responses to different resistance training frequencies and protocols in untrained males and females.

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

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

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

As a participant, you will be asked to partake in up to 10-22 sessions (depending on the group you are randomly assigned to), which include two identical pre and post sessions that consist of measuring: resting heart rate, blood pressure, height, and weight, pulse wave velocity, small and large arterial elasticity, one-rep max, and testing on Biodex while having a electromyography sensor placed on your legs. For one of these two sessions, you will be asked to come in hydrated (which will be tested via urine sample) and 8-hours fasted. The middle 6-18 sessions will consist of approximately 20 minutes of resistance training with and without blood flow restriction cuffs (depending on the group you are assigned to). The total time commitment is 6-10 hours. All data will be confidential by being collected by Murat Karabulut, Patrick Murphy, Brittany Esparza, and Danny Dominguez and later stored in a locked file cabinet for 3 years.

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

Do you have any questions now? If you have questions later, please contact me by email at Patrick.Murphy01@utrgv.edu

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

BIOGRAPHICAL SKETCH

Patrick Gage Murphy, Bachelor’s degree in Exercise Science May 2015 acquired from The University of Texas at Brownsville, Master’s degree in Exercise Science May 2017 acquired from the University of Texas Rio Grande Valley, 113 1st Street West, Rosebud, Alberta, CANADA T0J 2T0.